ME1381

PRICE $5.00

NASA Tracking Station
P. O. Box 1947
Titusville, Florida 32780

POWER SUPPLY

INSTRUCTION MANUAL

KEPCO INC.®

131-38 SANFORD AVENUE • FLUSHING, N. Y. 11352
Area Code 212 IN 1-7000 • TWX # 212-539-6623

TECHNICAL MANUAL

REGULATED POWER SUPPLY

MODEL PAX 36—0.3CR
(KEPCO INC.)

MAY 20, 1965

PREPARED FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NO. .....

The Kepco equipment described in this instruction manual is of proprietary design, covered by one or more of the following United States patents, or by patents pending:

2,992,379	3,092,757
2,992,386	3,112,439
3,028,538	3,128,423
3,056,905	3,131,344
3,088,053	

The contents of this instruction manual are copyrighted. Reproduction of any part may only be made with the specific written permission of Kepco, Inc.

PB:is
32/65

©KEPCO, INC. 1965

LIST OF EFFECTIVE PAGES

(TOTAL NUMBER OF PAGES IS 52)
AS FOLLOWS:

PAGE NUMBER	ISSUE
TITLE	ORIGINAL
i	"
ii	"
iii	"
1-1 through 1-6	"
2-1 through 2-4	"
3-1 through 3-16	"
4-1 through 4-3	"
5-1 through 5-12	"
6-1 through 6-6	"

*AN ASTRISK INDICATES PAGES REVISED, ADDED OR DELETED BY THE CURRENT CHANGE.

A D D E N D U M

1.0 SCOPE

This technical manual contains instructions for the installation, operation, and maintenance of the PAX 36-0.3CR Regulated Power Supply, manufactured by KEPCO, INC., 131-38 Sanford Avenue, Flushing, New York 11352.

2.0 EQUIPMENT SUPPLIED

a) Regulated Power Supply, Model PAX 36-0.3CR
(Including Case and Bridge-Current Adjustment Resistor.)

3.0 EQUIPMENT REQUIRED BUT NOT SUPPLIED

a) Voltage Control Element.

4.0 LIST OF SEMICONDUCTORS AND FUSES:

REFERENCE DESIGNATION	DESCRIPTION	MANUFACTURER AND MFR. NO.*	KEPCO PART NO.
Q101,102	Transistor,PNP	Delco 2N174	119-0016
Q201	Transistor,NPN	General Electric 2N336A	119-0056
Q202	Transistor,PNP	Hughes 2N1131A	119-0055
Q203	Transistor,NPN	General Electric 2N336A	119-0056
Q204	Transistor,PNP	Hughes 2N1131A	119-0055
CR201,202	Rect. Si-Pigtail	Semicon Inc. SM-140	124-0028
CR203	Rect. Si-Pigtail	Semicon Inc. SM-110	124-0133

Digitized by the Internet Archive
in 2026

https://archive.org/details/manualsplus_12213

REFERENCE DESIGNATION	DESCRIPTION	MANUFACTURER AND MFR. NO.*	KEPCO PART NO.
CR204, 205 206, 207	Rect. Si-Pigtail	Semicon, Inc. SM-140	124-0028
CR208	Zener Diode	North American Electronics 1N3026B	121-0036
CR209	Zener Diode	North American Electronics 1N821	121-0041
CR210	Rect. Ge-Pigtail	General Electric 1N-91	122-0007
CR211, 212	Rect. Si-Pigtail	Electronic Devices 124-0178	124-0178
F201	Fuse, 0.5A Slo-Blo	Bussman MDL-1/2	141-0036

*Note: Replacement parts may be ordered from KEPCO, INC. Orders should include Kepco Part Number and descripition.

The manufacturer's name and part number listed for each item on replacement parts list, represents at least one source for that item and is listed solely for the convenience of Kepco equipment owners in obtaining replacement parts locally. We reserve the right to use equivalent items from alternate sources.

TABLE OF CONTENTS

Paragraph		Page
	SECTION I - INTRODUCTION	
1-1	Scope of Manual	1-1
1-3	General Description	1-1
1-5	Accessories	1-1
1-9	Specifications, General	1-2
1-10	Specifications, Voltage Regulation Mode	1-3
1-11	Specifications, Current Regulation Mode	1-3
1-12	Specifications, Performance	1-4
1-13	Specifications, Physical	1-5
	SECTION II - INSTALLATION	
2-1	Unpacking and Inspection	2-1
2-3	Terminations	2-1
2-5	AC Power Requirements	2-2
2-8	Grounding	2-2
2-10	Isolation	2-2
2-12	Operational Check	2-3
	SECTION III - OPERATING PROCEDURES	
3-1	General	3-1
3-3	Equations, Showing the Operation of the Kepco Bridge	3-1
3-5	Adjustments for Exact Programming	3-2
3-16	Programming Output Voltage With Resistance	3-5
3-19	Remote Error Sensing	3-6
3-22	Constant Current Operation	3-7
3-27	Programming By Conductance	3-9
3-31	Programming Output Voltage With External Voltage	3-11
3-36	Series Operation of PAX Modules	3-13
3-39	Parallel Operation of PAX Modules	3-14
	SECTION IV - THEORY OF OPERATION	
4-1	General	4-1
4-3	Circuit Description	4-1
	SECTION V - MAINTENANCE	
5-1	General	5-1
5-3	Internal Adjustment Procedure, Current Limiting	5-1
5-5	Installation and Adjustment of Optional Control Components	5-2
5-9	Trouble Shooting	5-5
5-12	Power Supply Measurements	5-5
	SECTION VI - ELECTRICAL PARTS LIST	6-1 through 6-6

LIST OF ILLUSTRATIONS

Figure		Page
1-1	KEPCO Model PAX, Regulated Power Supply	iii
1-2	Model PAX With Accessories	iv
1-3	Mechanical Outline Drawing	1-6
2-1	Terminations	2-1
2-2	Conversion to 230V AC Line Operation	2-2
2-3	Operational Check	2-3
2-4	Simplified Diagram of Model PAX Power Supply With Rear Terminal Connection Detail	2-4
3-1	Kepco Comparison Bridge, Simplified	3-1
3-2	Programming Ratio Calibration, Method #1	3-3
3-3	Programming Ratio Calibration, Method #2	3-4
3-4	Programming Ratio Calibration, Method #3	3-5
3-5	Connections for Resistance Programming	3-6
3-6	Connections for Remote Error Sensing	3-7
3-7	Connections for Constant Current Operation	3-8
3-8	Connections for Conductance Programming	3-10
3-9	Connections for Voltage Programming	3-12
3-10	Series Connection of PAX Supplies	3-13
3-11	Parallel Connection of PAX Supplies	3-14
3-12	Parallel Operation of PAX Supplies	3-15/ 3-16
4-1	PAX Module, Simplified Schematic	4-2
5-1	Location of Current Limit Adjust Potentiometer Location of Mounting Screws	5-3
5-2	Installation of Optional Control Components	5-4
5-3	Power Supply Measurements	5-6
5-4	Approximation of A Four Terminal Network	5-8
5-5	Component Location, Main Chassis	5-9
5-6	Component Location, PCB-1	5-10
5-7	Main Schematic	5-11/ 5-12

LIST OF TABLES

Table		Page
1-1	Output Ranges and Maximum Output Impedance	1-5
	Field Replacement List	Appendix

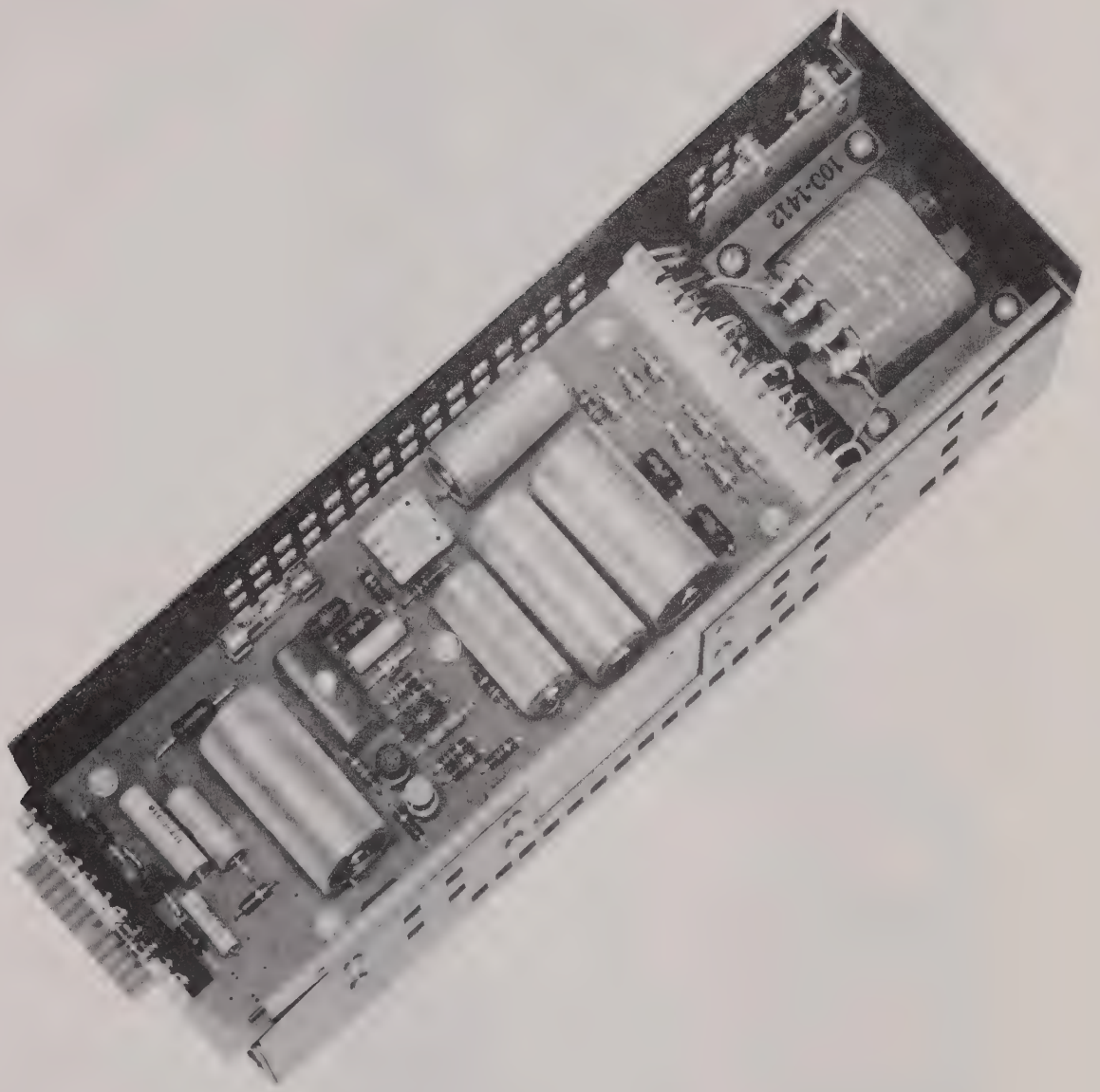


FIG. 1-1 KEPCO SERIES PAX POWER SUPPLY

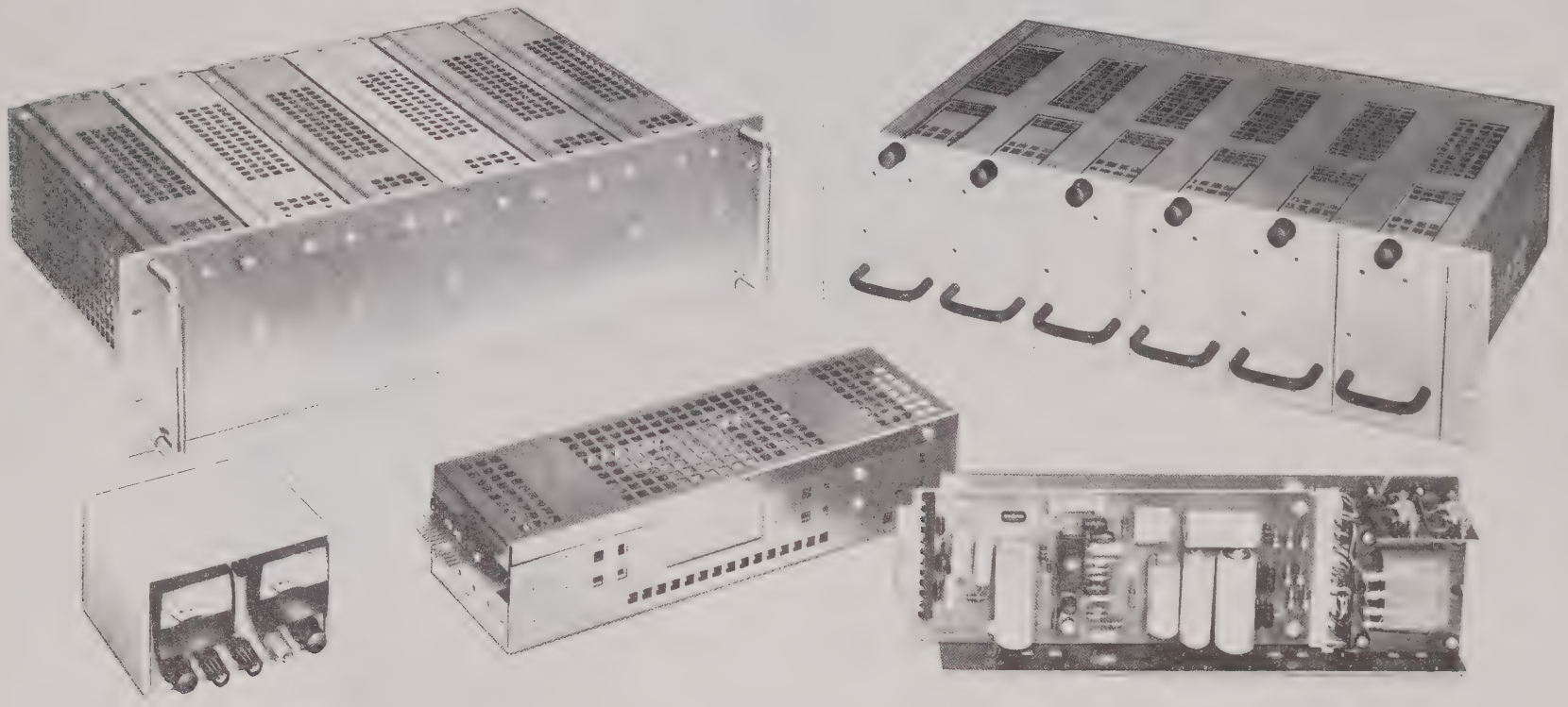


FIG. 1-2 MODEL PAX & ACCESSORIES

SECTION I - INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This manual contains instructions for the installation, operation, and maintenance of the KEPCO Series PAX Power Supplies.

1-3 GENERAL DESCRIPTION

1-4 The KEPCO Series PAX design group consists of precision regulated power supplies with low output ripple. The specifications and electrical characteristics of these units are identical, except as noted in Table 1-1. These power supplies are modular units, intended to be operated with external controls. They have provisions for remote error sensing and are fully programmable for automatic or remote operation. All models in the PAX design group are also identical in their mechanical outlines, and are designed into a packaging configuration which permits a great variety of installations.

1-5 ACCESSORIES (OPTIONAL, NOT SUPPLIED)

1-6 The PAX Power Supplies are supplied without a line cord and a control resistor, the latter must be connected externally or internally according to the applications of these units. (Refer to Section III - OPERATING PROCEDURES). Connections to and from the power supply, including the AC line connection, can be made either by means of the barrier strip, TB201, or with an optional mating plug to the printed circuit board connector. (Refer to Par. 2-3 "TERMINATIONS").

1-7 ELECTRICAL ACCESSORIES

a) Mating connector for PAX printed circuit board:
KEPCO Part No. 143-0200
Cinch Part No. 250-12-37-200
Methode Part No. CD 612S P7

b) Bridge current adjustment potentiometer, 1 K, W.W. 20 PPM.
KEPCO Part No. 115-0739
Bourns Part No. 3067S-1-102

c) Voltage adjustment potentiometers (based on 1 ma bridge current).

ADJUSTMENT RANGE	KILOHMS	KEPCO P/N	MANUFACTURER P/N
5 volts	5K	115-1363	Bourns, No. 3067P-1-502
10 volts	10K	115-1706	Bourns, No. 3067P-1-103
20 volts	20K	115-1728	Bourns, No. 3067P-1-203

d) CMH Control Adapter: The PAX Power Supply Module can be converted into a precision laboratory bench supply by adding a case and a CMH Adapter. The CMH Adapter mates with the PAX supply to form a single unit providing high resolution voltage control, metering of voltage and current as well as output binding posts, a three-wire safety line cord, ON-OFF switch and line voltage signal lamp complete this practical accessory.

1-8 MECHANICAL ACCESSORIES (Refer to Fig. 1-2)

a) Panel Adapter: RAP 6-1: 5¼" H x 2 25/32" W (includes handle and fastener) - for mounting six cased units in Rack Cabinet RA 6-6.

b) Panel Adapter: RAP 7-1: 3½" H x 4 7/32" W (includes handle and fastener) - for mounting four cased units in Rack Cabinet RA 7-4.

c) Filler Panels: RFP 7-1 (Fills one space in RA 7-4)
RFP 7-2 (Fills two spaces in RA 7-4)
RFP 6-1 (Fills one space in RA 6-6)
RFP 6-2 (Fills two spaces in RA 6-6)
RFP 6-3 (Fills three spaces in RA 6-6)

d) Rack Cabinet:
RA 6-6: 5¼" H x 19" W x 13 3/4" D - for mounting six units.
RA 7-4: 3½" H x 19" W x 13 3/4" D - for mounting four units.

Special back plates with mounted mating connectors for printed circuit board connectors adapt the rack cabinets for plug-in mounting of the PAX units.

RA 6-6BP: For plug-in mounting six units in Rack Cabinet RA 6-6.
RA 7-4BP: For plug-in mounting four units in Rack Cabinet RA 7-4.

e) Rack Adapters:
RA 12-1: 3¼" H x 19" W - for mounting a single PAX-C unit.
RA 11-6: 5¼" H x 19" W - for end mounting six PAX-C units.
RA 13-4: 3½" H x 19" W - for end mounting four PAX-C units.

1-9 SPECIFICATIONS, GENERAL (See also Table 1-1)

a) Input Requirements: 105-125V AC or 210-250V AC, 50-440 cps single phase.

b) Ambient Operating Temperature: -20°C to +50°C maximum.

c) Storage Temperature: -40°C to +85°C maximum.

d) Isolation Voltage: A maximum of 500 volts can be connected between the chassis and either output terminal.

1-10 SPECIFICATIONS, VOLTAGE REGULATION MODE

a) Regulation:

1) Line: Less than 0.05% or 1 mv output voltage change for 105-125V AC or 210-250V AC line variation, at any output voltage within the specified range.

2) Load: Less than 0.05% or 1 mv output voltage change, whichever is greater, for no load to full load change at any output voltage within the specified range.

b) Stability: Output voltage varies less than 0.05% or 3 mv, whichever is greater, over a period of 8 hours after warmup, measured at constant line voltage, load and ambient temperature. (Refer to Par. 1-12a).

c) Temperature Coefficient: Output voltage changes less than 0.05% per °C. (Refer to Par. 1-12a)

d) Ripple: Less than 0.25 mv rms.

e) Recovery Time: 50 microseconds.

f) Output Impedance: Specified for each model within the load frequency range shown in Table 1-1. Above 10 kc include the reactive impedance of the effective series inductance as indicated.

1-11 SPECIFICATIONS, CURRENT REGULATION MODE (EXTERNAL SENSING)

a) Output Range: Current regulation from 1 ma to 100% of the maximum rated current.

b) Compliance: Voltage compliance range is zero to 100% of the maximum output voltage.

For any selected current value, the output voltage is automatically varied throughout the compliance range as required to regulate the output current through a variable load.

c) Regulation:

1) Line: For 105-125V AC or 210-250V AC line variations, output current changes less than 0.1% when the specified voltage sample is maintained across the external sensing resistor.

2) Load: For the maximum change is load resistance, within the rated compliance range, output current changes less than 0.1% when the specified voltage sample is maintained across the external sensing resistor.

The sensing resistor is chosen to produce a one volt drop at the maximum operating current. A separate control is used externally to provide current adjustability.

d) Stability: Output current varies less than 0.1% or 1 ma, whichever is greater, over a period of 8 hours after warmup. Measured at constant line voltage, load and ambient temperature. (Refer to Par. 1-12a)

e) Temperature Coefficient: Output current changes less than 0.1% per °C. (Refer to Par. 1-12a)

f) Ripple: Less than 0.1% of maximum current rms.

1-12 SPECIFICATIONS, PERFORMANCE

a) Controls: PAX Modules are ordinarily supplied without controls. External fixed or variable programming resistors are used to control the output. Optionally, on special order, a built-in trimmer can be provided for up to 20 volts adjustment range. Stability and temperature coefficient criteria require the use of high quality LTC, 20 PPM wire wound elements for programming.

b) Programming: Terminals provide for resistive programming of voltage or current at approximately 1000 ohms per volt. Programming terminals are also provided for programming by means of remotely located voltage or current signals. Optionally, on special order, a built-in trimmer can be provided to adjust the control ratio over a 10% range so that exact value fixed programming resistances can be used conveniently.

c) Current Limit Control: A single-turn control provides adjustable current limiting from 25% to 150% of rated full-load current.

d) Short Circuit Protection: Unique current limiting circuitry permits continuous operation into a short circuit without the aid of fuses, circuit breakers or relays. Output returns instantly to the operating voltage when the overload is removed.

e) Remote Error Sensing: Error sensing terminals enable specified voltage regulation to be maintained directly at the load by compensating for voltage drops up to 0.5 volts across each load supply lead.

f) Series/Parallel Operation: Series connection of identical units is possible up to the specified isolation voltage limit, and provided the necessary precautions are taken. (See Par. 3-9) PAX supplies can be parallel connected and will share the load by means of their current limiting feature. (See Par. 3-8).

g) Cooling: Heat removal is by natural convection, without blowers.

h) Overshoot: No output voltage overshoot from turn-on, turn-off, or power failure for output settings above 25% of maximum rated output voltage. Below 25%, output voltage overshoot is a function of load current and is negligible for loads in excess of 10% of the maximum rated load current.

1-13 SPECIFICATIONS, PHYSICAL (Refer to Fig. 1-2 Mechanical Outline Drawing)

a) Dimensions: 2½" H x 3 13/16" W x 12 13/16" D. Uncased for chassis mounting.

b) Cased Units: To specify cased unit, add suffix "C" to model number; e.g., PAX 36-0.3C for module with case.

c) Cased Dimensions: 2 11/16" H x 4 1/8" W x 13 3/16" D.

d) Terminals and Controls: 11-terminal barrier strip and provision for acceptance of a 12-terminal printed circuit connector for AC input, DC output, error sensing and programming control functions. Output terminals are isolated from ground and either positive or negative output may be grounded.

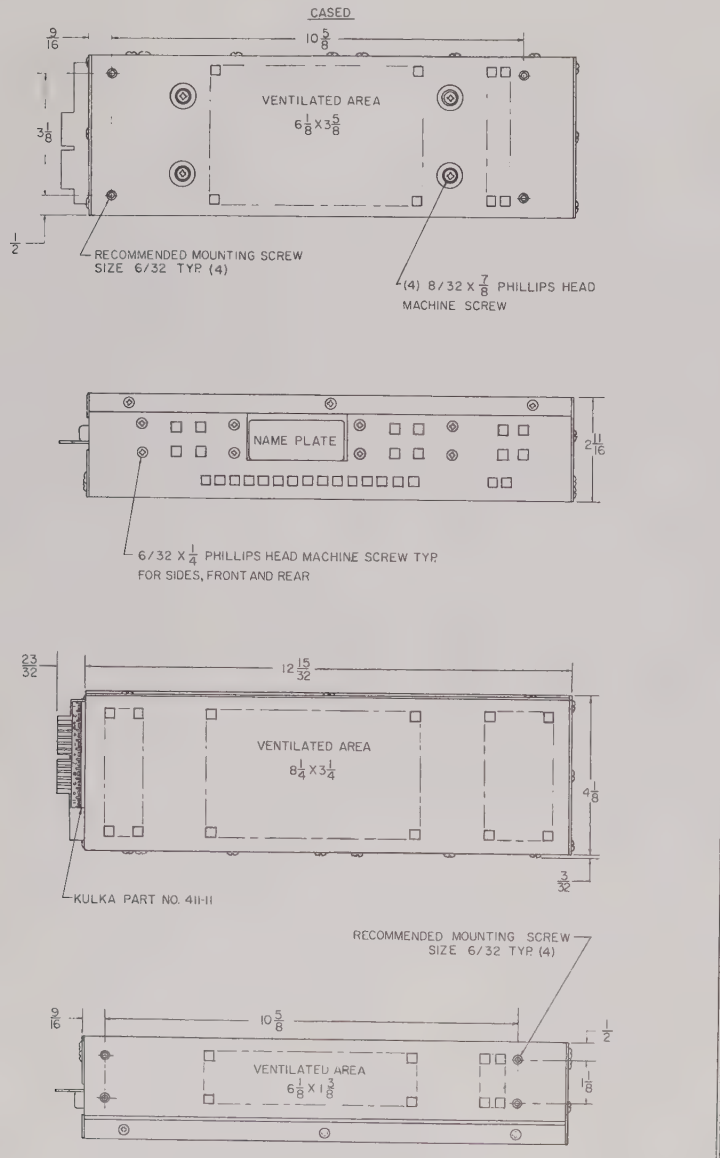
e) Standard Finish:

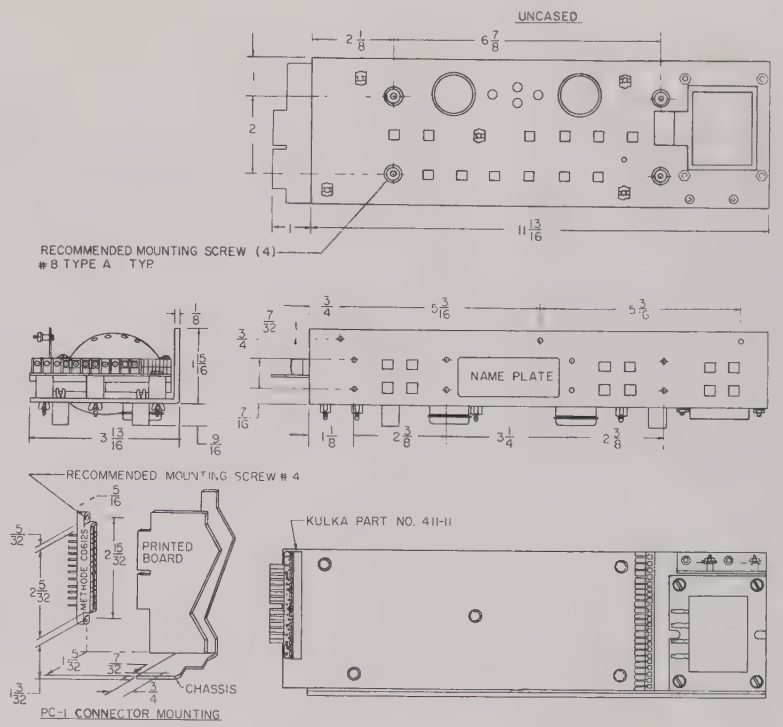
1) Case and Chassis: Blue anodized aluminum.

2) Panel Adapter: Etched aluminum - brushed and coated (Special finishes to order).

TABLE 1-1 OUTPUT RANGES AND MAXIMUM OUTPUT IMPEDANCE, PAX POWER SUPPLY MODULES

MODEL NO.	(DC) OUTPUT VOLTS	(DC) OUTPUT CURRENT	(OHMS) IMPEDANCE DC-100cps	(OHMS) IMPEDANCE 100cps-1kc	(OHMS) IMPEDANCE 1kc-100kc
PAX 7-1	0-7 volts	0-1A	0.004	0.02	0.01+1μh
PAX 15-0.75	0-15 volts	0-0.75A	0.01	0.02	0.01+1μh
PAX 21-0.5	0-21 volts	0-0.5A	0.025	0.02	0.01+1μh
PAX 36-0.3	0-36 volts	0-0.3A	0.06	0.02	0.01+1μh
PAX 72-0.15	0-72 volts	0-0.15A	0.25	0.02	0.01+1μh
PAX 100-0.1	0-100 volts	0-0.1A	0.5	0.02	0.01+1μh





NOTES

1 THIS DRAWING USED FOR PAX 36-0.3, PAX 36-0 3 HS, PAX 7-1, PAX 7-1HS, PAX15-0 75, PAX15-075HS, PAX21-05, PAX21-0 5HS, PAX72-015, PAX72-015HS, PAX100-01, PAX100-01HS

2. MATERIAL, COVER #16 GAUGE ALUM HEAVY ANODIZED, BLUE FINISH CHASSIS 1/8 THICK ALUM #3003-H14 HEAVY ANODIZED, BLUE FINISH

3 REFER TO KEPCO CATALOG FOR DETAILED SPECIFICATIONS

PC-1 CONNECTOR FUNCTION	TERMINAL BD FUNCTION
1	1
2	2 — SWITCHED AC POWER
3	3 GND
4	4 MINUS ERROR SENSING
5	5 MINUS OUTPUT
6	6 PLUS OUTPUT
8	7 PLUS ERROR SENSING
9	8 VOLTAGE CONTROL
10	9 NULL JUNCTION
11	10 REF VOLTAGE
12	11 REF RESISTANCE

FOR ALTERNATE CONNECTIONS SEE KEPCO MANUAL

FUSE DATA			
MODEL	FUSE SIZE	115VAC	230 VAC
PAX 36-0.3	F 20	0 5 AMP	0 3 AMP
PAX 7-1	F 20	0 5 AMP	0 3 AMP
PAX 15-0.75	F 20	0 5 AMP	0 3 AMP
PAX 21-0.5	F 20	0 5 AMP	0 3 AMP
PAX 72-0.15	F 20	0 5 AMP	0 3 AMP
PAX 100-01	F 20	0 5 AMP	0 3 AMP
PAX 36-0.3 HS	F 20	0 5 AMP	0 3 AMP
PAX 7-1 HS	F 20	0 5 AMP	0 3 AMP
PAX 15-0.75 HS	F 20	0 5 AMP	0 3 AMP
PAX 21-0.5 HS	F 20	0 5 AMP	0 3 AMP
PAX 72-0.15 HS	F 20	0 5 AMP	0 3 AMP
PAX 100-01 HS	F 20	0 5 AMP	0 3 AMP

FIG. 1-3 MECHANICAL OUTLINE DRAWING

2-1 UNPACKING AND INSPECTION

2-2 This power supply has been inspected and tested at the factory prior to packing and it is shipped ready for operation. After careful unpacking, inspect the instrument for shipping damage before attempting to operate it. Perform the operational check as described in Par. 2-11, below. If there is any indication of damage, file a claim immediately with the responsible transport service.

2-3 TERMINATIONS (Refer to Fig. 2-1)

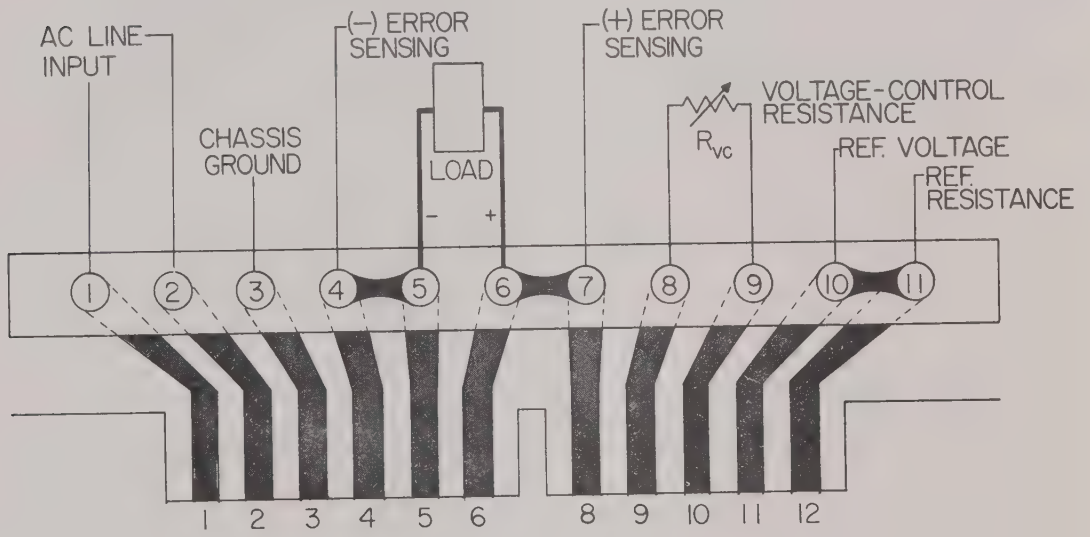


FIG. 2-1 PAX POWER SUPPLY, TERMINATIONS

2-4 All input and output connections on the PAX Power Supplies are terminated at the miniature barrier strip and the associated printed circuit board connector. Necessary connections to the supply can therefore be made two ways:

a) Directly at the barrier strip (correct lugs which fit the individual terminals are supplied).

or b) Through the printed circuit board connector using the correct mating plug (Refer to Par. 1-5, ACCESSORIES).

NOTE: In the following instructions reference is made to the barrier terminals only. See Fig. 2-1 for correlation between barrier strip terminal numbers and printed circuit connector pin numbers.

2-5 AC POWER REQUIREMENTS

2-6 This power supply is normally shipped for operation on a nominal 115V AC, single phase line. If 230V AC operation is desired, the transformer primary link connections must be changed as shown in Fig. 2-2 below. For either line voltage, the input connections must be made to terminals (1) and (2) on the rear barrier strip. If a three-wire line cord is used, the third wire (AC ground) must be connected to terminal (3).

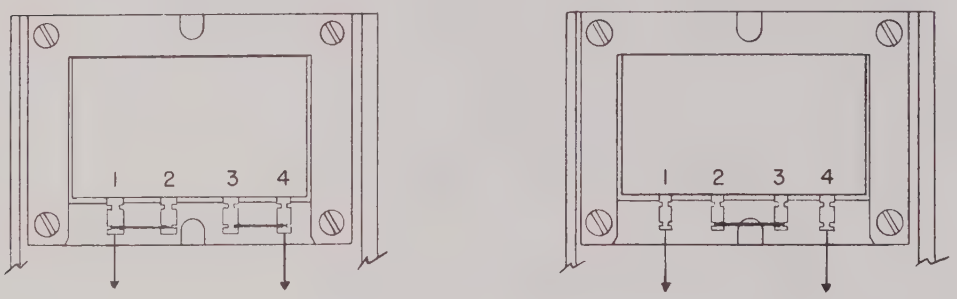


FIG. 2-2 CONVERSION TO 230V AC LINE OPERATION

2-7 PROCEDURE:

a) Disconnect power supply from line.

b) Remove bare wire jumpers between terminals (1) and (2) as well as (3) and (4).

c) Connect bare wire jumper between terminals (2) and (3).

d) Replace 0.5A fuse with 0.3A.

2-8 GROUNDING

2-9 For safety reasons it is imperative that the metal chassis be kept at ground potential. If a three-wire safety line cord and a properly grounded outlet is used, this is taken care of automatically. However, if only a two-wire line cord is used, or an adapter for a three-wire line cord is used, the pigtail wire of the adapter, or the metal chassis of the power supply must be returned to a good AC ground.

2-10 ISOLATION

2-11 The DC output terminals of the PAX Power Supply are isolated from the AC powerline and from the chassis, except for a capacitive connection from the positive output to chassis. Since no DC connection to the chassis exists, either side of the supply may be grounded, or a maximum of 500V can be connected between chassis and either output terminal.

2-12 OPERATIONAL CHECK

2-13 After AC power connections have been made as described in Par. 2-4, a functional check can be performed as follows:

Apply line power and connect a voltmeter between output terminals (5) and (6). Observe polarity. Note: The resistor which is connected between terminals (8) and (9) serves as the voltage control resistor R_{VC}. It is for preliminary check-out purposes only and regulation or stability measurements should not be attempted with it in place.

The output voltage measured on the connected meter should be proportional to the resistance across terminals (8) and (9). Since a nominal 1000 Ohm/V control ratio is used in the PAX Power Supplies, the output voltage will be approximately equal to the number of kilohms used. This completes the operational check of the PAX Power Supply.

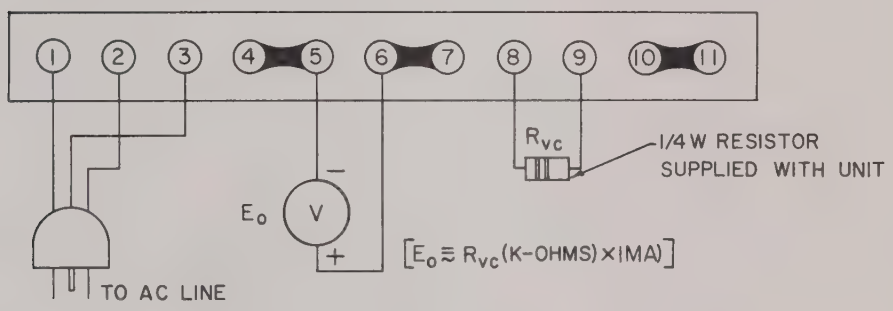


FIG. 2-3 OPERATIONAL CHECK

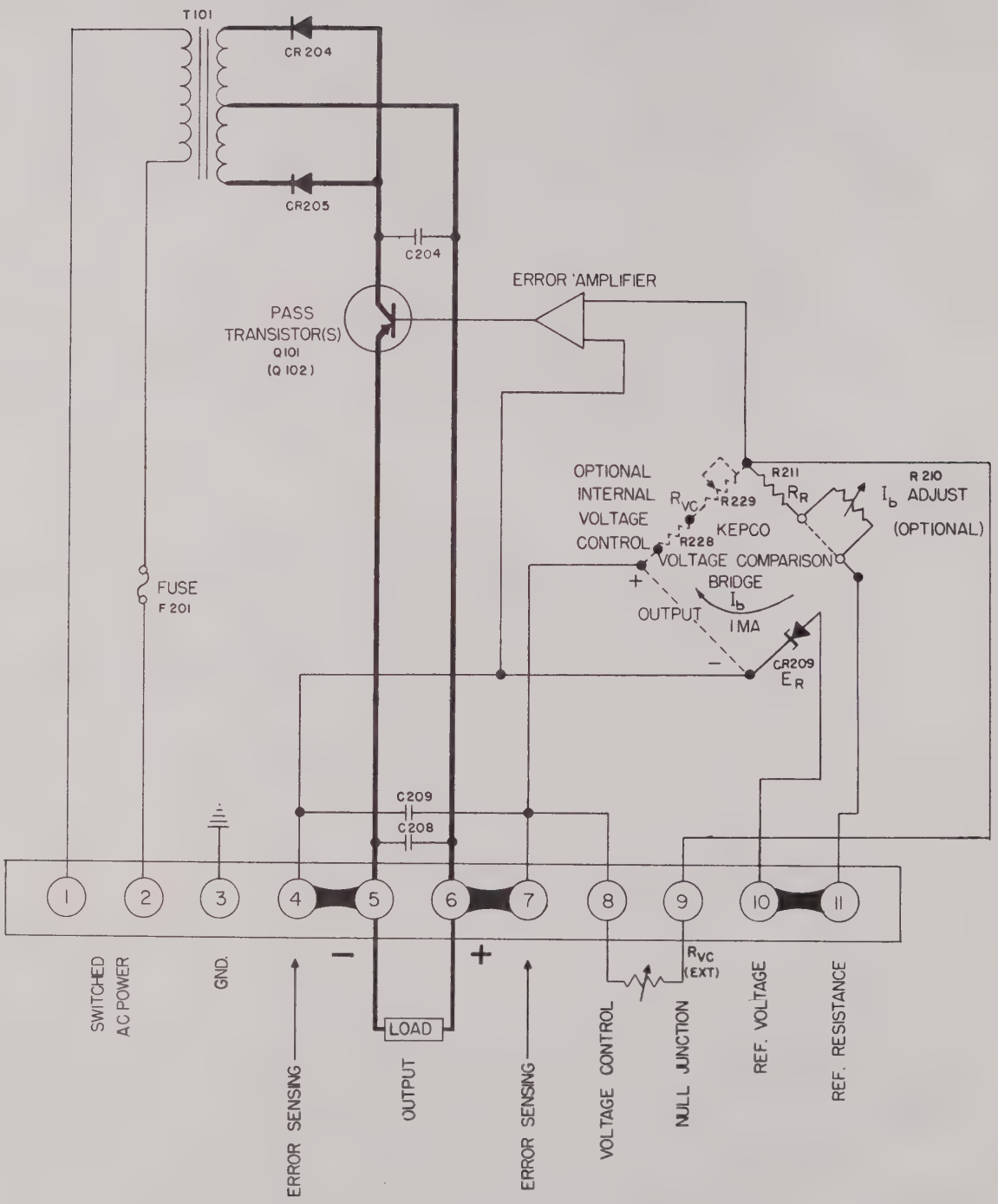


FIG. 2-4 SIMPLIFIED DIAGRAM OF MODEL PAX POWER SUPPLY WITH REAR TERMINAL CONNECTION DETAIL

3-1 GENERAL

3-2 A few general remarks may be in order to familiarize the user of this equipment with the terminology and the basic equations pertaining to the operation of the Kepco PAX Power Supply.

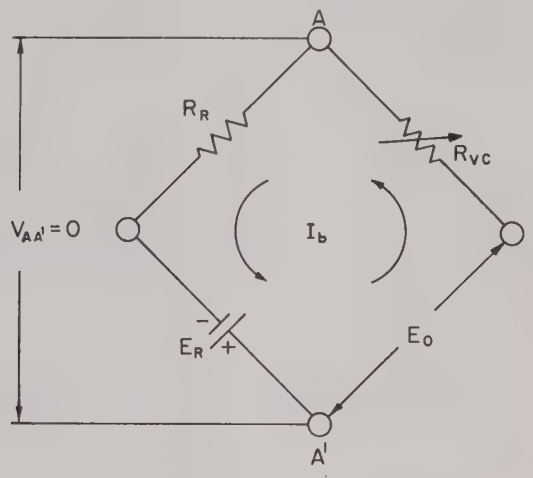


FIG. 3-1 KEPCO COMPARISON BRIDGE, SIMPLIFIED

3-3 EQUATIONS SHOWING THE OPERATION OF THE KEPCO BRIDGE

3-4 The following relationships govern the operation of the Kepco bridge at balance, i.e., with $V_{AA'} = 0$:

a) $$\frac{E_o}{E_r} = \frac{R_{vc}}{R_r} \quad (1)$$

$$\frac{E_r}{R_r} = I_b \quad (2)$$

$$E_o = I_b R_{vc} \quad (3)$$

Where: E_o = Output Voltage
E_r = Reference Voltage
R_r = Reference Resistance
R_{vc} = Control Resistance
I_b = Bridge Current.

b) The ratio of the number of ohms control - resistance needed per volt output is termed the "CONTROL RATIO". It is a nominal 1000 ohm/volt in the PAX Series Power Supplies.

c) As can be seen from equation (1), the output voltage E_o can be controlled by varying any one of the three quantities. Rewriting equation (1) we have:

$$E_o = \frac{E_r}{R_r} \times R_{vc}.$$

The ratio $\frac{E_r}{R_r}$ constitutes the bridge current I_b. (Eq. 2).

d) Therefore, we can write: $E_o = I_b R_{vc}$ (Eq. 3). Making I_b a precision quantity (precision bridge current adjustment is described in Par. 3-5), establishes a precise programming ratio, so that the accuracy of E_o is solely dependent upon R_{vc}. This mode of operation is referred to as "RESISTANCE PROGRAMMING" and is covered in detail in Par. 3-16.

e) Rewriting Equation (1), $E_o = E_r \frac{R_{vc}}{R_r}$, we can make E_r the variable which controls E_o. This type of control is referred to as "VOLTAGE PROGRAMMING" and is covered in Par. 3-31.

f) Many other modes of control are of course possible; some of the more general ones are described in the following paragraphs. For a more extensive treatment and a more detailed theoretical view of power supply applications, see the "Kepco Power Supply Handbook", available from your Kepco Representative or directly from Kepco Applications Engineering Department.

NOTE: For all programming and adjustment components, use high quality, wire-wound, resistors with a T. C. of 20 p.p.m. or better.

3-5 ADJUSTMENTS FOR EXACT PROGRAMMING RATIO

3-6 Referring to Equation (3): $E_o = I_b R_{vc}$, it is obvious that if I_b = 1 ma, for each volt of output voltage E_o, 1000 ohms of Control Resistance R_{vc} is needed. The "Programming Ratio" of 1000 ohms per volt is therefore based on the bridge current, I_b.

In the PAX Series Power Supplies, this bridge current is about 10% higher than 1 ma.

Again referring to $E_o = I_b R_{vc}$ (3), we see that if R_{vc} is made zero (shorted out), E_o should be zero. However, a small negative offset voltage will be found at the output under this condition.

Both "inaccuracies", the small offset voltage as well as the slightly larger bridge current, have been purposely designed into the PAX Power Supplies in order to simplify precision adjustment of the Programming Ratio.

Quite a number of methods are possible towards that end. The accuracy of the calibration is only limited by the precision of the test equipment in the laboratory. Since the availability of this equipment will vary from laboratory to laboratory, several procedures are described on the following pages.

3-7 METHOD #1 (ACCURACY DEPENDING UPON MA METER AND R_{VC})

3-8 EQUIPMENT REQUIRED:

a) Precision ma meter, Weston Model 931 or equivalent.

b) Precision resistor 1K ohm ± 0.5% or better.

c) Multimeter or other voltmeter for null indicator.

d) Single pole, single throw switch.

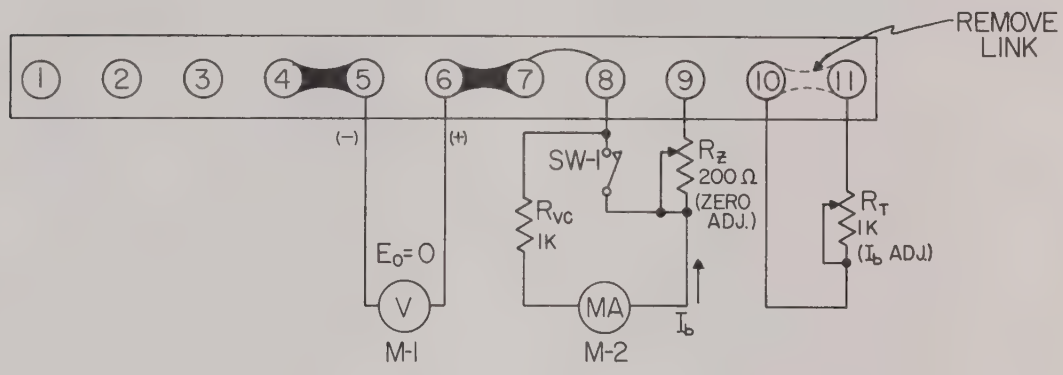


FIG. 3-2 PROGRAMMING RATIO CALIBRATION, METHOD #1

3-9 PROCEDURE:

a) Connect calibration set-up as shown in Fig. 3-2.

b) Connect PAX Power Supply to AC line. With SW-1 open, approximately 1 volt will be read at the output voltmeter, M-1.

c) Adjust R_t until milliammeter M-2 reads exactly 1 ma.

d) Disconnect power supply from the line and mark zero reading of output voltmeter and reconnect to line.

e) Close SW-1 and adjust R_z exactly to this established zero point.

f) Repeat (b), (c), (d), and (e) until no further change is observed.

3-10 METHOD #2 (ACCURACY DEPENDING UPON CELL AND R_{VC})

3-11 EQUIPMENT REQUIRED:

a) Mercury cell, 1.35V.

b) Precision resistor 1.35K ± 0.1%.

c) Multimeter or other voltmeter as a null indicator.

d) DPDT switch.

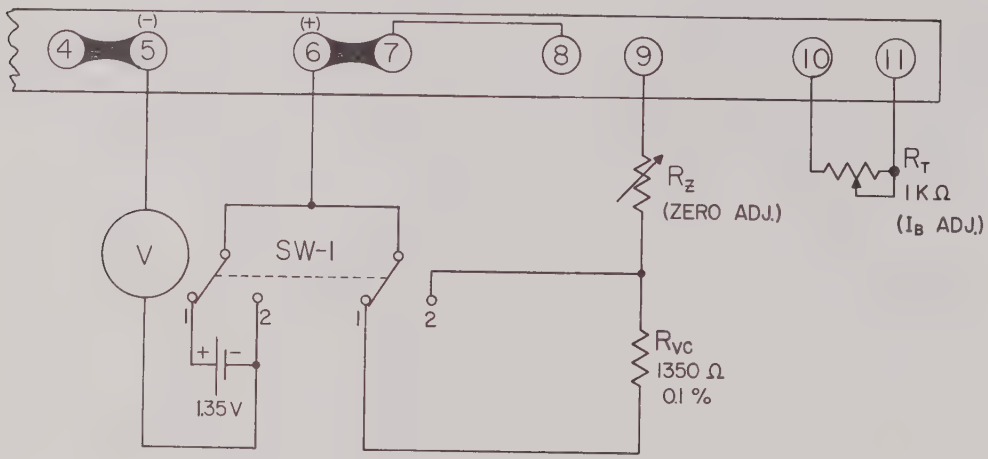


FIG. 3-3 PROGRAMMING RATIO CALIBRATION, METHOD #2

3-12 PROCEDURE

a) Connect calibration set-up as shown.

b) Connect power supply to line. With SW-1 in Pos. 1, adjust R_t to zero volts on the null meter.

c) Transfer SW-1 to Pos. 2. Adjust R_z to zero volts on the null meter.

d) Return SW-1 to Pos. 1 and repeat (b) and (c) again until no further change is observed on the voltmeter.

3-13 METHOD #3 (ACCURACY DEPENDING UPON VOLTMETER AND R_{VC})

3-14 EQUIPMENT REQUIRED:.

a) Precision differential - or digital voltmeter.

b) Any value precision resistor ± 0.1%.

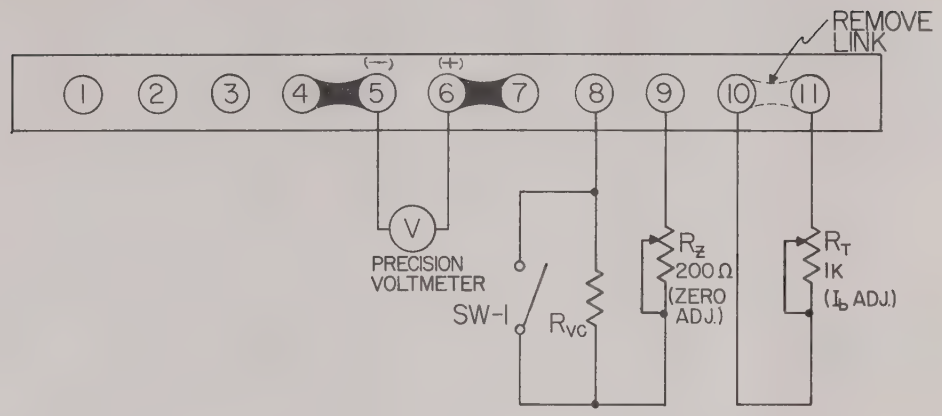


FIG. 3-4 PROGRAMMING RATIO CALIBRATION, METHOD #3

3-15 PROCEDURE

a) Connect calibration set-up as shown in Fig. 3-4.

b) With SW-1 closed, adjust R_z for zero volts on the precision voltmeter.

c) Open SW-1 and adjust R_t exactly 1 volt per 1000 ohms.

d) Repeat (b) and (c) until no further change is observed on the voltmeter.

3-16 PROGRAMMING OUTPUT VOLTAGE WITH RESISTANCE

3-17 The output voltage of the PAX Power Supply can be varied by means of a control resistance connected between terminals (8) and (9) of the barrier strip. This resistance may be fixed, continuously adjustable, or stepped*, or it may be a combination of these.

The value of the output voltage is given by Equation (1):

$$E_o = R_{vc} \left(\frac{E_r}{R_r}\right)$$

Since $\frac{E_r}{R_r} = I_b$ (2), it follows that $E_o = I_b R_{vc}$ (3).

Referring to Equation (3), we see that since I_b is 1 ma in the PAX Supplies (and can be precision adjusted as shown in Par. 3-5), for every volt of output, 1000 ohms control resistance must be provided. This corresponds to a "Programming Ratio" of 1000 ohms per volt.

*NOTE: When fixed resistors are switched as the voltage control resistance, the switching device must have "Make before break" contacts in order that the control circuit does not open during transfer. While the

steady state current through R_{VC} is only 1 ma, it will rise to considerably higher peak values when larger voltage steps are programmed. The programming resistors therefore must absorb these peak currents which consist of energy stored in the output capacitor. Consequently, it is recommended that the dissipation rating of these programming resistors is made several times the steady state power dissipated in them.

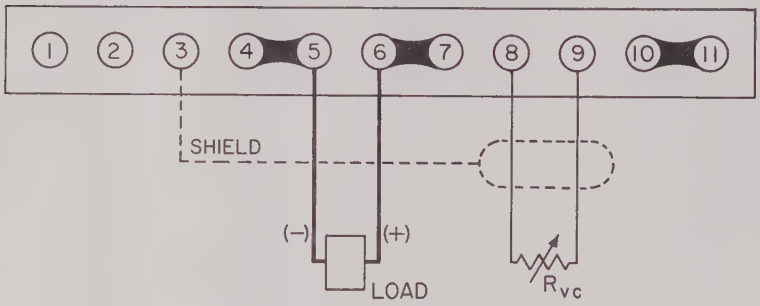


FIG. 3-5 CONNECTIONS FOR RESISTANCE PROGRAMMING

3-18 PROCEDURE (Refer to Fig. 3-5)

a) Determine value of programming resistor(s) for output voltage desired.

b) Using two-wire, shielded cable, connect the chosen resistors to terminals (8) and (9). Connect the shield to terminal (3).

3-19 REMOTE ERROR SENSING

3-20 The error sensing terminals (4) and (7) on the barrier strip are the input connections to the power supply's regulating system and are normally connected to the output terminals (5) and (6) by means of removable links. Specified performance will, therefore, be maintained at these points with the links in place. Since voltage drop across the load wires will degrade regulation directly at the load, however, the links connecting the sensing leads to the output terminals can be removed and the sensing leads connected directly to the load to compensate for the voltage drop across the load wires. Up to 0.5 volt drop in each load wire can be compensated for, using remote error sensing.

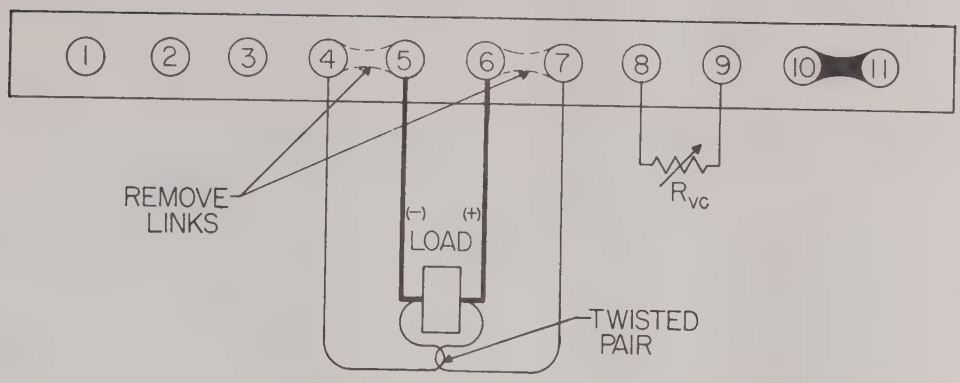


FIG. 3-6 CONNECTIONS FOR REMOTE ERROR SENSING

3-21 PROCEDURE (Refer to Fig. 3-6)

a) Remove the jumper links between terminals (4)-(5) and (6)-(7).

b) Use a twisted wire pair and connect terminal (4) to the negative side of the load and terminal (7) to the positive side of the load. The use of twisted load wires to terminals (5) and (6) is recommended to reduce the wiring inductance and thus improve the transient recovery time and enhance AC stability of operation.

NOTE: An accidental open circuit in the remote sensing circuit will sharply degrade the regulating function and cause the output voltage and ripple to rise. In addition, an open load circuit, leaving the error sensing terminals connected to the load, may be damaging to the supply since the load current will attempt to flow through the sensing circuit.

When using remote error sensing, the power supply should be OFF when load and sensing connections are being made.
Be sure to connect the load before connecting the sensing wires and conversely, remove the sensing wires before removing the load leads.

3-22 CONSTANT CURRENT OPERATION

3-23 In the constant current operating mode, the voltage comparison bridge is interconnected with an external current sensing resistor, R_S, and a current control, R_C, (as shown in Fig. 3-7) to maintain a constant voltage drop across R_S. In this way, an adjustable constant load current is obtained. Characteristic of the constant current supply is the ability to change its output voltage automatically in order to maintain a constant current through a range of possible load

resistances. The range of output voltage that the supply can deliver and simultaneously maintain constant current, is referred to as the "COMPLIANCE VOLTAGE".

3-24 The current sensing resistor R_S is chosen to develop a 1 volt drop at the maximum desired current. It is calculated by dividing this current into one volt. The value of R_S is not critical and can be the nearest standard resistance value available. Several facts should be kept in mind, however, when choosing R_S. A compromise must be made between a large and a small value. While a large value is desirable for good current regulation, it is less so in view of the power dissipated across it. It must be remembered that all the load current is flowing through R_S and the input to the regulator is connected across it. It is, therefore, vital that all extraneous changes across R_S, i.e., resistance change due to temperature, are kept to a minimum. A high quality, low T.C. (20 PPM) resistor, at least ten times the actual wattage needed, is therefore strongly recommended.

3-25 The current control resistor, R_C, is chosen on the basis of the control ratio of the Kepco comparison bridge, and V_S, the maximum voltage across R_S. If R_S was selected for 1 volt drop, then V_S = 1 volt and $R_C = V_S$ (control ratio), or R_C = 1 volt $(\frac{1000 \text{ ohm}}{1 \text{ volt}})$ = 1000 ohms. A high quality, low T.C. (20 PPM) resistor is recommended for R_C.

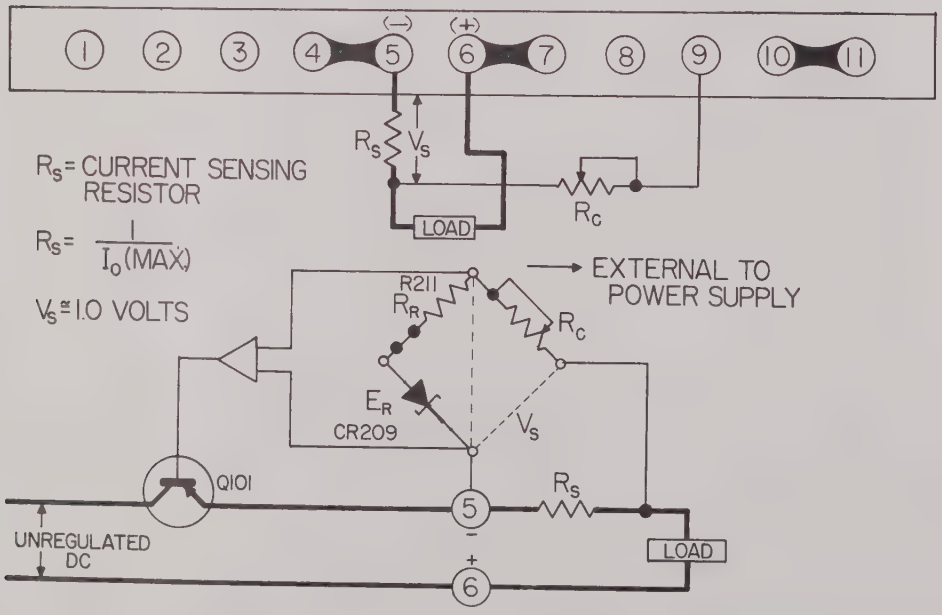


FIG. 3-7 CONNECTIONS FOR CONSTANT CURRENT OPERATION

3-26 PROCEDURE (Refer to Fig. 3-7)

The actual set up procedure for current regulation is perhaps best shown by a practical example. A PAX 36-0.3 is to be set up for current regulated output from 30 ma to 300 ma.

a) R_S is chosen by: $R_S = \frac{1 \text{ volt}}{0.3A} = 3.33$ ohm

$P_{diss} = V_S \, I_{max.} = 1$ volt $(0.3A) = 0.3$ watts.

Three 10 ohm, 1 w, wire-wound resistors connected in parallel will be satisfactory.

b) The control resistance R_C is found by calculating its limits:

$R_C(max.) = V_S(max.) \times \text{control ratio} = 1V \times \frac{1000 \text{ ohms}}{V} = 1000$ ohms.

$R_C(min.) = V_S(min.) \times \text{control ratio} = 0.1V \times \frac{1000 \text{ ohms}}{V} = 100$ ohms.

As R_C is therefore varied from 100 ohms to 1000 ohms, the regulated current will vary from 30 to 300 ma, and the compliance voltage from approximately zero to 35 volts.

c) Since, in the above example, the sensing voltage across R_S went below 1 volt at the low current output, the current regulation may not be sufficient for the purpose intended. (Specifications are based on a 1 volt sample.) To insure regulation figures within specifications, we must calculate R_S under minimum current conditions.

$V_S min. = 1$ volt

$I_{min.} = 0.03A$

$$R_S = \frac{1 \text{ volt}}{0.03A} = 33.3 \text{ ohms}$$

The actual power dissipation of R_S is given by:

$P_{diss} = V_S(max.) \times I_L(max.) = 10V \times 0.3A = 3$ watts

(Three 100 ohm, 10 w, wire-wound resistors connected in parallel, will be satisfactory.)

R_C will now be:

$R_C(max.) = V_S(max.) \times \text{control ratio} = 10V \times 1000 \text{ ohm/V} = 10$ K ohm

$R_C(min.) = V_S(min.) \times \text{control ratio} = 1V \times 1000 \text{ ohm/V} = 1$ K ohm

3-27 PROGRAMMING BY CONDUCTANCE

3-28 For special applications, the output voltage E_O can be adjusted by varying the bridge current. The relationship governing this type of programming is:

$$E_o = \frac{E_r}{R_r} (R_{vc}) (G),$$

or $$E_o = \frac{E_r}{R_R + R_X} (R_{vc})$$

Where: $G = \frac{1}{R_X}$ = programming conductance

E_o = output voltage

E_r = Reference voltage

R_{vc} = Control resistance

R_R = reference resistance

R_X = programming resistor

Since $\frac{E_r}{R_r} = I_b$ and $E_o = I_b R_{vc}$, the output voltage varies directly as I_b changes. Changing I_b with the help of an additional resistor in series with R_R results in an inversely proportional change of I_b, since now $I_b = \frac{E_r}{R_R + R_X}$. This method of output voltage adjustment is, therefore, referred to as conductance programming.

3-29 Conductance programming is inherently non-linear when analyzed in terms of resistance. It can, nevertheless, be very useful, especially over a limited range and for small changes in output voltage. Another distinctive advantage of this type of programming is the "built-in" safety feature. Should the programming circuit open accidently, the programming resistance becomes infinite, the conductance is zero, and consequently, the output voltage becomes zero.

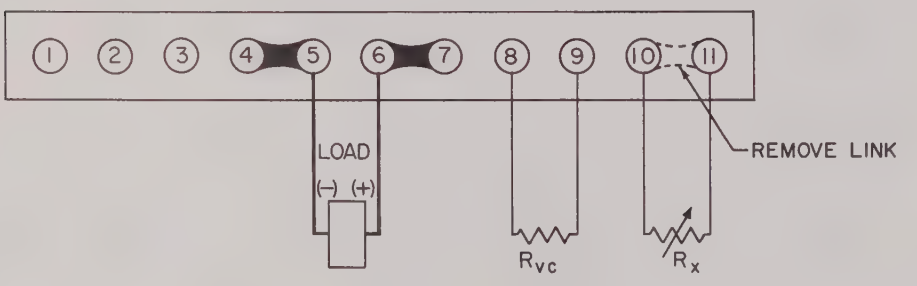


FIG. 3-8 CONNECTIONS FOR CONDUCTANCE PROGRAMMING

3-30 PROCEDURE (Refer to Fig. 3-8)

Example: E_o desired = 3.5V

a) Select R_{vc} for maximum desired output voltage E_o.

$$R_{vc} = \frac{E_o}{I_b}, \quad R_{vc} = \frac{5V}{1 \text{ ma}} = 5K \text{ ohms}$$

b) A change of E_o to 3 volts requires a bridge current change of:

$$I_b = \frac{E_o}{R_{vc}} = \frac{3 \text{ volts}}{5K \text{ ohms}} = .6 \text{ ma.}$$

c) Since $I_b = \frac{E_r}{R_r} = 1$ ma, the additional resistance needed is:

$$I_b(R_R+R_x) = E_r, \; R_x = \frac{E_r}{I_b} = R_R \quad \text{or} \quad R_x = \frac{6 \text{ volts}}{0.6 \text{ ma}} - 6K = 4K \text{ ohms.}$$

A 4K ohm, W.W., low T.C. potentiometer will change the output voltage from 3 to 5 volts when varied from zero to 4K ohms.

NOTE: A word of caution may be in order in regard to the changing of the bridge current. The 1 ma value has been selected for greatest stability in the zener reference circuit. A large departure from this value is not advisable. If a ±50% change in I_b is not sufficient to achieve the desired voltage swing, an external reference supply can be used.

3-31 PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL VOLTAGE

3-32 The output voltage (E_o) of the PAX Power Supply can be varied by means of another external voltage source. This external programming voltage takes the place of and functions as the internal reference voltage of the PAX supply. The output voltage (E_o) "follows" the programming source and maintains a value that remains in a constant proportion to it. The relationship governing this type of programming can be expressed by the equation:

$$\frac{E_o}{E_i} = \frac{R_{vc}}{R_c}$$

Where: E_o = output voltage to be programmed.

E_i = programming voltage (input).

R_{vc} = voltage control resistance of the supply to be programmed. (R_{vc} can be either internally or externally connected).

R_c = external programming resistor (coupling resistor).

3-33 The values of the above quantities can be chosen to suit the particular application, although a few basic facts must be considered concerning their selection. E_o is, of course, limited by the maximum capability of the supply to be programmed. E_i can be any variable DC source having parameters at least as good as the desired E_o, and being able to deliver the necessary I_b. The resistors R_{vc} are selected by first determining I_b, the desired bridge current.

Since I_b is supplied by E_i and also subtracts from the load current of the supply to be programmed, it should be kept as low as possible, but not under 100 μa.

(3) $R_{vc} = \frac{E_o}{I_b} = \frac{30V}{5\ ma} = \underline{\underline{6K}}$ (4) $R_c = \frac{E_i}{I_b} = \frac{10V}{5\ ma} = \underline{\underline{2K}}$

Power dissipated in R_{vc} = 30V (.005) = .15W (use 1W).

Power dissipated in R_c = 10V (.005) = .05W (use .5W).

3-36 SERIES OPERATION OF PAX MODULES

3-37 General: Kepco PAX Modules can be series-connected for increased voltage output provided the specified limits on voltage to chassis are not exceeded. When series-connected, the supplies should be protected by means of a semiconductor diode across the output terminals of each power supply, as shown in Fig. 3-10. The peak inverse rating of these diodes must be at least as large as the output voltage of the supply to which they are connected. The continuous current rating of the diodes should be at least as great as the largest short-circuit current of the interconnected supplies.

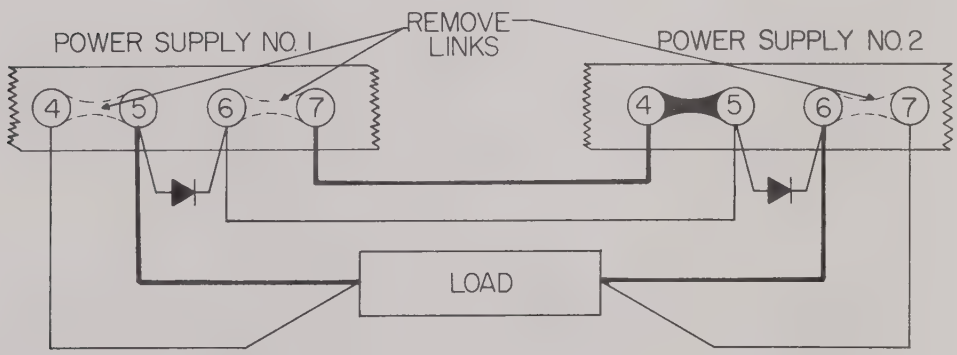


FIG. 3-10 SERIES CONNECTION OF PAX SUPPLIES

3-38 PROCEDURE

a) Connect load as shown in Fig. 3-10. Keep voltage drop in load wires as low as practical by using heavy gauge wire.

b) Connect protective diodes across respective output terminals.

c) Remove jumpers as shown and connect error sensing leads. These leads carry negligible current and can be approximately #20 gauge wire.

d) Turn supplies on and adjust voltage on either control as required.

3-39 PARALLEL OPERATION OF PAX MODULES

3-40 Two identical PAX power supplies may be operated in parallel for increased load-current output. Each supply is set approximately to the desired output voltage with its respective Current Limiting Adjustment set to the maximum clockwise position. After paralleling the two power supplies, one of them (supply #1) will inherently be at a slightly higher output voltage than the other (supply #2). Consequently, supply #1 will deliver all the load current up to the setting of its Current Limiting Adjustment. As the load is increased beyond this limit of supply #1, supply #2 takes over and delivers the additional current. The Current Limiting Adjustment of supply #1 can now be decreased, so that approximately equal current sharing is obtained. Fig. 3-12 shows in form of a diagram, how the two supplies operate in parallel, with their respective Current Limit Adjustments in maximum clockwise position. It will be obvious from the diagram, that the areas of load regulation are within the output current bands of the individual supplies only. Therefore, load regulation cannot be measured from zero to twice the load current for example, but only within the individual load current bands. Error-sensing as described in Par. 3-18, (from either supply) may be used if precise regulation at the load is required.

NOTE: When paralleling power supplies, care should be exercised to avoid turning the voltage control of only one supply close to zero. This precaution is necessary to prevent possibly damaging currents in the voltage control resistor as its limiting resistance is lowered.

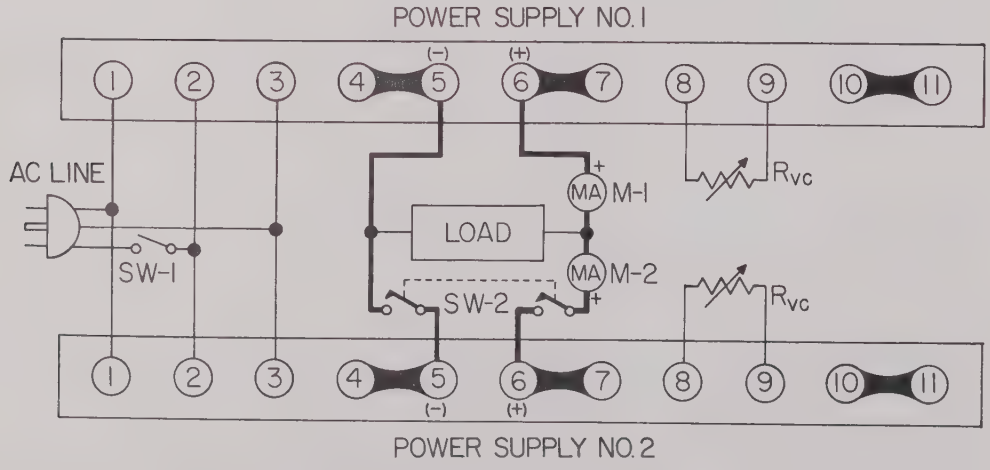


FIG. 3-11 PARALLEL CONNECTION OF PAX SUPPLIES

3-41 PROCEDURE (Refer to Fig. 3-12)

a) Connect units as shown in Fig. 3-12. Open SW-1 and SW-2 and connect to line.

b) Close SW-1 and adjust both units to the approximate output voltage desired.

c) Close SW-2. Observe load current meters M1 and M2. Adjust Current Limit Adjust potentiometer R203 on the unit showing the higher current on its load current meter. Turn R203 counter clockwise until currents on M-1 and M-2 are approximately equal.

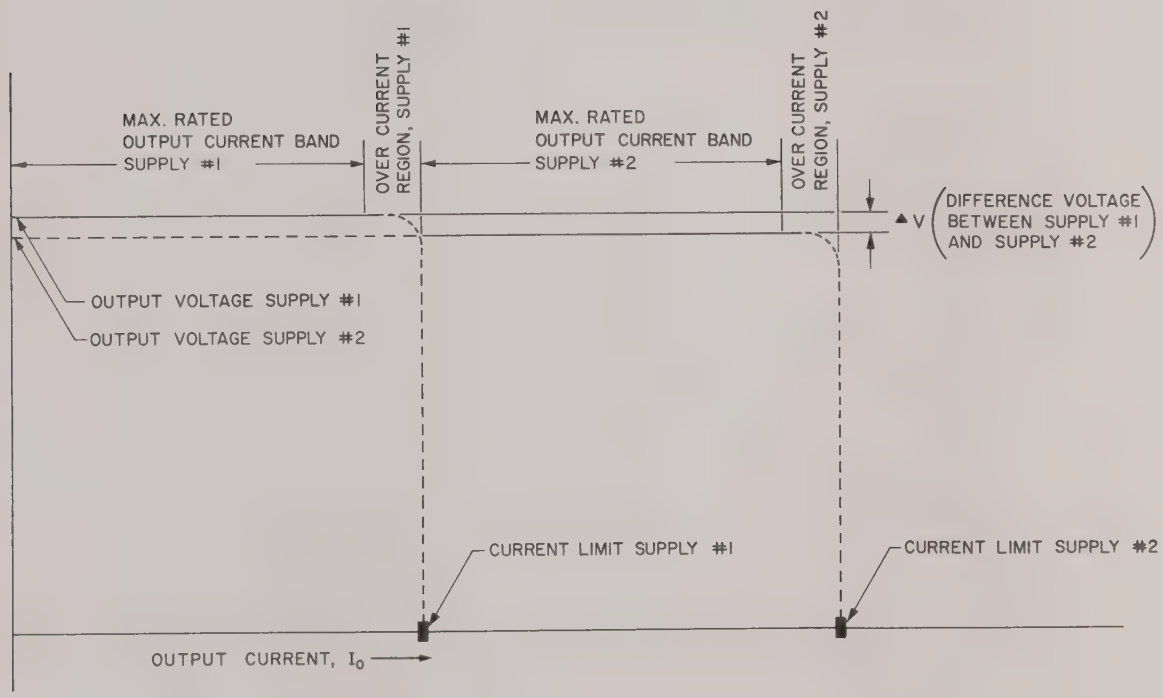


FIG. 3-12 PARALLEL OPERATION, PAX POWER SUPPLIES

SECTION IV - THEORY OF OPERATION

4-1 GENERAL

4-2 The KEPCO Model PAX Power Supply consists basically of four major sections; first, the main power source with pass element and driver; second, the error signal amplifier; third, the comparison bridge, and finally, the auxiliary supplies.

4-3 CIRCUIT DESCRIPTION (Refer to Fig. 4-1 and Main Schematic)

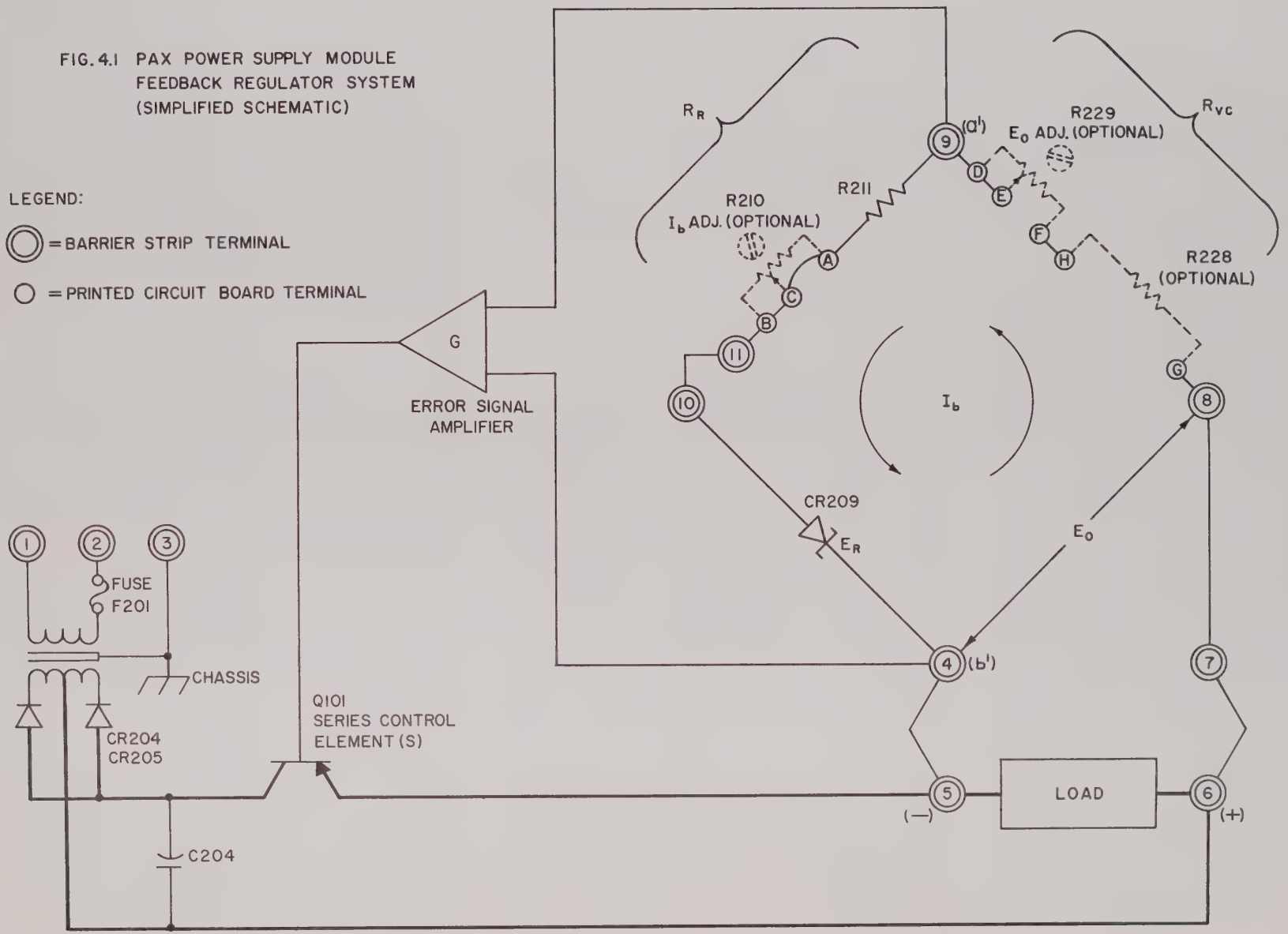
a) The Main Power Supply: The main DC power is derived from a center-tapped winding on T101 and is rectified in a conventional full-wave arrangement with capacitor-input filter (CR204, CR205, C204). The main power supply delivers the operating voltages for the pass elements as well as the output current.

b) The Pass Element: The pass element (or series control transistor) Q101 is connected in series with the output terminals so that the unregulated voltages from the rectifier circuit is divided between it and the load. By changing the equivalent resistance of the series control element, the voltage drop across it is made to change in such a way as to maintain a constant output voltage. The base drive current for the pass element to effect this change is supplied by Q204, which in turn is driven by the control signal from the error signal amplifier. PAX power supplies above 0.15A output current have an additional, parallel pass element (Q102).

c) The Error Signal Amplifier: This DC coupled, voltage amplifier consists of Q201, Q202 and Q203. Its function is to amplify the signal, derived from the comparison bridge, to a level suitable to drive Q204. Its operating point is set by R203 in such a way that any increase in output current will tend to saturate the transistor and thereby limit the drive signal to Q204.

d) The Comparison Bridge: This four-arm electrical bridge circuit is the regulating and controlling element in many KEPCO Power Supplies. In the PAX Model it consists of CR209 (E_r). R211 (R_R), the output voltage (E_o), and the voltage control resistance (R_{VC}) which is to by applied externally between terminals (8) and (9) on the front barrier strip. As shown in Fig. 4-1, a reference voltage (E_r) in series with the reference resistance (R_R) is continuously compared with the output voltage, (E_o) in series with the voltage control resistance, R_{VC}. At balance, a constant bridge current (I_b) is flowing through the bridge, keeping the error signal at bridge terminals (a') and (b') at approximately zero volts. Any deviation from the set output voltage will tend to change I_b in the sensing half of the bridge and thereby produce an error signal at the bridge

FIG. 4.1 PAX POWER SUPPLY MODULE
FEEDBACK REGULATOR SYSTEM
(SIMPLIFIED SCHEMATIC)



terminals (a') and (b'). This error signal is then amplified and acts as a control signal for the series regulator transistor, changing the voltage drop across it in such a way as to compensate for the change in output voltage.

e) Auxiliary Supplies:

1) Amplifier Power Supply:- This full-wave, capacitor-filtered DC source consists of a center-tapped winding on T101, silicon rectifiers CR201 and CR202, filter capacitor C201 and limiting resistor R101. It provides the operating voltage for the amplifier and the comparison bridge circuit.

2) Driver Collector Supply:- A half-wave, capacitor-filtered supply is derived from a winding on T101, rectified by silicon rectifier CR203 and filtered by R213 and C203. It delivers collector voltage to driver transistor, Q204.

3) I_{CO} Supply:- This full-wave, capacitor-filtered supply is derived from the same winding on T101 which supplies the main DC power. CR206 and CR207 are the silicon rectifiers and C205 serves as the filter capacitor. This supply has the function of providing the turn-off bias for the series pass transistor, especially at higher ambient temperatures.

SECTION V - MAINTENANCE

5-1 GENERAL

5-2 Conservative rating of all components and avoidance of congested layout in the KEPCO Model PAX Power Supply should keep maintenance to a minimum. However, if component failure does take place, the ease of disassembling the printed circuit board plus the component location drawings and information in this section should help to keep the "down time" of the equipment to a minimum.

5-3 INTERNAL ADJUSTMENT PROCEDURE FOR CURRENT LIMITING CONTROL (Refer to Fig. 5-1)

5-4 A single turn potentiometer, R203, conveniently located on the topside of the printed circuit board serves as an adjustment for limiting the output current through the range of 25 to 150% of its maximum rated value. It is factory-adjusted for approximately 25% above the maximum rated output current, and has to be reset only if a component should have to be replaced or if other than the preset limit is desired.

A convenient way to make the adjustment is as follows:

a) Set up supply to draw the maximum desired output current and monitor the output with an oscilloscope having a vertical sensitivity of at least 1 mv/cm.

b) Turn the current limit adjustment, R203, to its maximum clockwise position as viewed from the topside.

c) Turn power on and observe ripple. Decrease the current limiting by slowly rotating R203 counterclockwise until output ripple increases substantially. Back off on R203 until output ripple appears normal again. Short circuit supply by connecting a DC ampere meter across its output terminal. The short-circuit current will be approximately 25% above the set limit.

NOTE: A too close setting of the current limit adjustment may result in premature limiting of the output current. It is, therefore, advisable to let the unit reach thermal equilibrium at its expected ambient temperature environment before the final adjustment is made.

5-5 INSTALLATION AND ADJUSTMENT OF OPTIONAL CONTROL COMPONENTS* (Refer to Fig. 5-1 and Fig. 5-2)

5-6 Disassembly of the Printed Circuit Board: The installation of the optional components can be readily accomplished by first removing the printed circuit board from the chassis assembly.

a) Remove the five mounting screws as indicated on Fig. 5-1. Remove PCB connector and lift PCB from assembly.

b) Install components as directed in the following paragraphs and as shown in Fig. 5-2.

c) Re-install PCB and replace mounting screws and proceed with alignment procedures.

5-7 Installation and Calibration of Bridge Current Adjustment (R210)*

a) Remove jumper between terminals marked "A" and "B".

b) Insert 1K ohm, W.W. potentiometer, Bourns "Trimpot" No. 3067S-1-102, KEPCO Part Number 115-0739 or equivalent in the space outlined on Fig. 5-2. Solder in place.

c) Turn potentiometer to its approximate mid-position. Install a precision resistor (R_{VC}) across barrier strip terminals (8) and (9) and connect a precision voltmeter across the output terminals (5) and (6). Since the bridge current (I_b) is 1 ma, and the control ratio is 1 K ohm/V, the output voltage (E_o) will be equal to $E_o = I_b R_{VC}$. (i.e. for each 1000 ohms of voltage control resistance (R_{VC}) one volt of output voltage will appear across the output terminals.)

d) Turn unit on and read the output voltage. Adjust R210 until E_o is exactly equal to the number of kilohms of R_{VC}. The accuracy of the adjustment is limited only by the tolerance of R_{VC} and by the accuracy of the voltmeter across the output terminals.

*PAX Modules having factory installed Bridge Current Adjustment bear the letter "R" behind the type designation, e. g. "PAX 36-0.3R" PAX Modules with factory installed voltage control resistors bear a special,4 digit type designation, e.g. "7001".

5-8 Installation and Adjustment of the Output Control Potentiometer

a) If the PAX Power Supply is used as a fixed source, the voltage control resistance, R_{VC}, can be internally installed on the printed circuit board as indicated in Fig. 5-2.

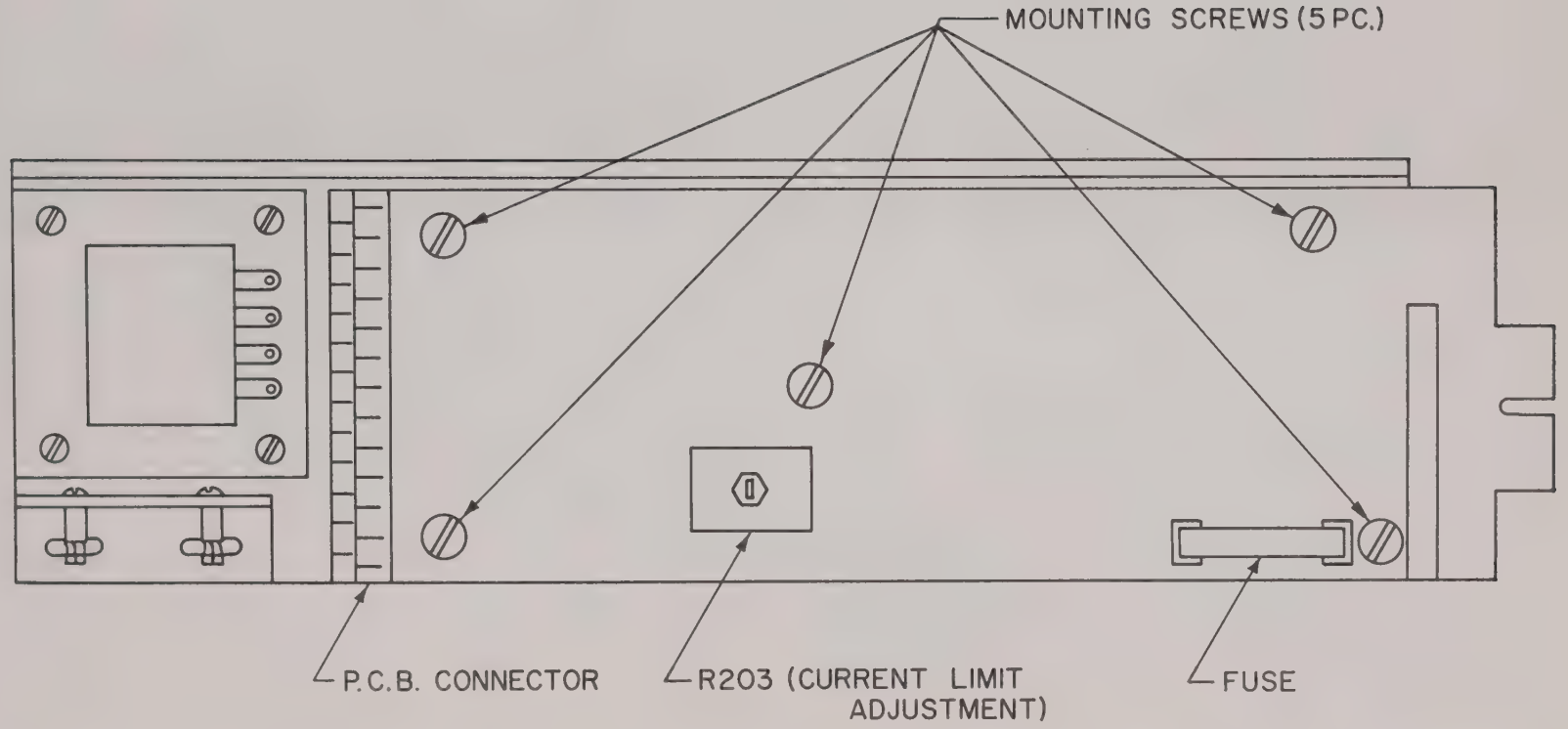


FIG. 5-1, LOCATION OF CURRENT LIMITING ADJUSTMENT POTENTIOMETER. LOCATION OF MOUNTING SCREWS.

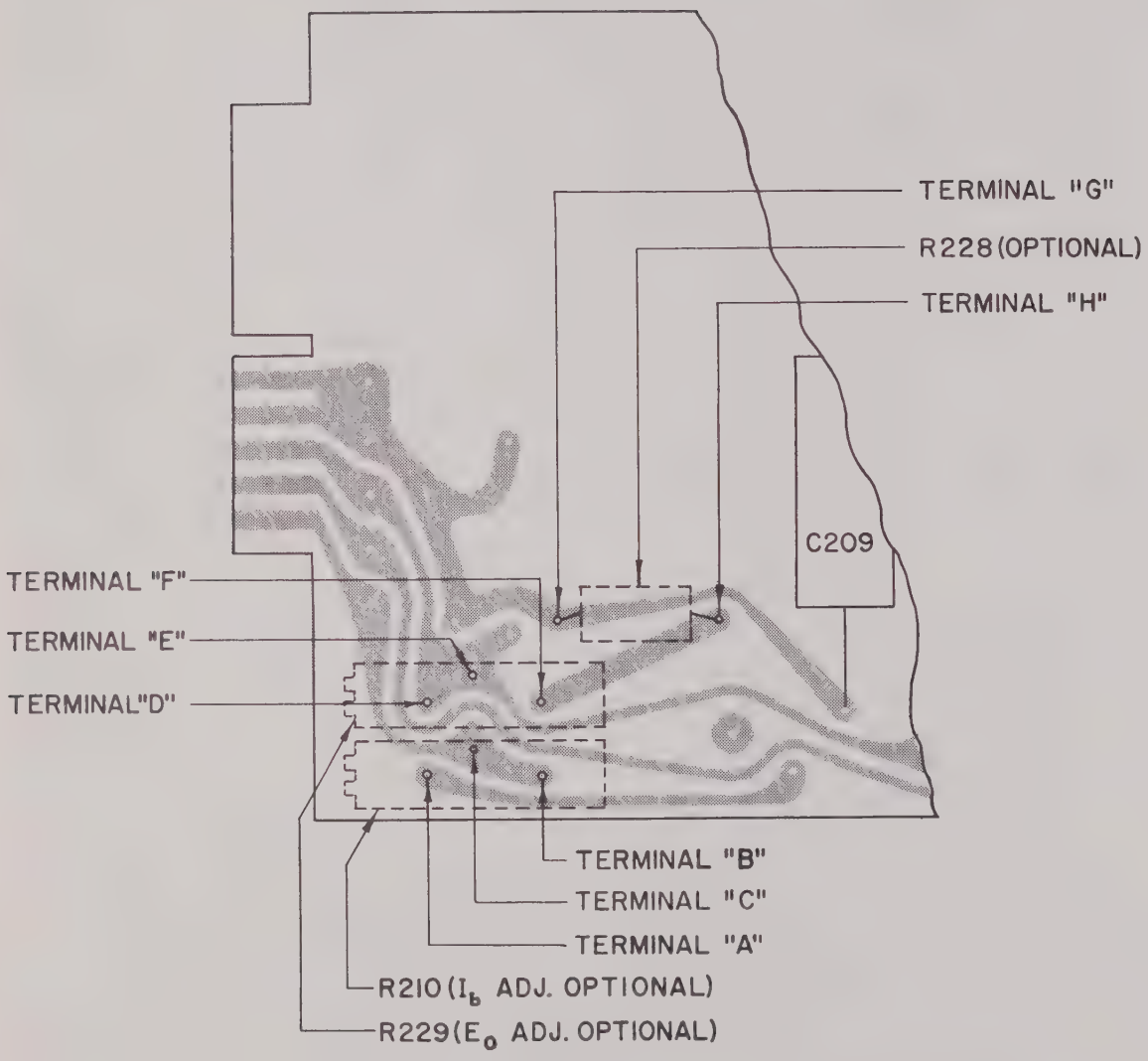


FIG. 5-2, INSTALLATION OF OPTIONAL CONTROL COMPONENTS

b) Several configurations of R_{VC} are possible.

1) R_{VC} can be a fixed resistor, installed between points D and F.

2) R_{VC} can be made up entirely as a variable resistor by inserting a 20K ohm potentiometer (Bourns "Trimpot" No. 3067-1-203, KEPCO Part Number 115-1728) into the space indicated and installing a wire jumper between points H and G. (This configuration is only possible for Models PAX 7-1 and PAX 15-0.75, since commercial wire-wound "Trimpots" are only available up to 20K ohms.)

3) For PAX Models exceeding 15 volts output voltage, a combination of "Trimpot" and fixed resistor can be installed for limited adjustment of the output voltage. Install the variable resistor as described in "2". Insert fixed resistor between points H and G. Any combination of fixed and adjustable resistors can be chosen as long as high quality wire-wound components with low temperature coefficient are used.

c) After installation of the desired components the power supply is adjusted to the chosen output voltage by varying R229 and monitoring the output with a precision voltmeter.

5-9 TROUBLE SHOOTING

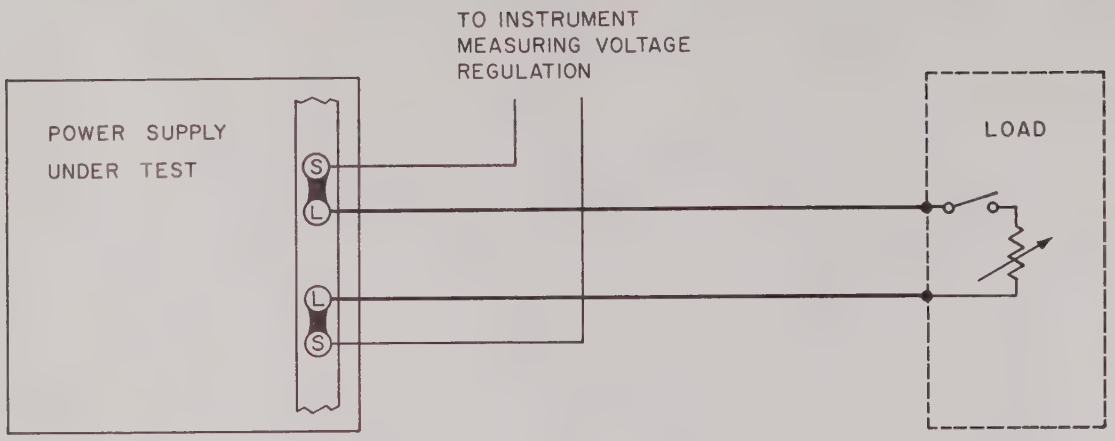
5-10 The use of high quality components in this power supply should assure long and trouble-free operation if the instrument is used within its specifications. If a component should fail, however, disassembly of the unit and part replacement are made convenient by the printed circuit board construction and sound mechanical engineering.

5-11 Servicing beyond simple part replacements should be attempted only by personnel thoroughly familiar with solid state components and with experience in closed loop circuitry. Since "trouble-shooting charts" containing resistance and voltage measurements at various places in the equipment are not very useful in feedback amplifiers, we have not included them in this manual. Presented instead is a fairly extensive circuit description (Section IV), detailed diagrams showing adjustments and parts location (See Fig. 5-1, 5-2, 5-5, and 5-6), as well as the Main Schematic, Fig. 5-7, which together should provide the necessary information for qualified personnel in the repair of this instrument. KEPCO Field Engineers and the KEPCO Repair Department are always available for prompt service in difficult cases.

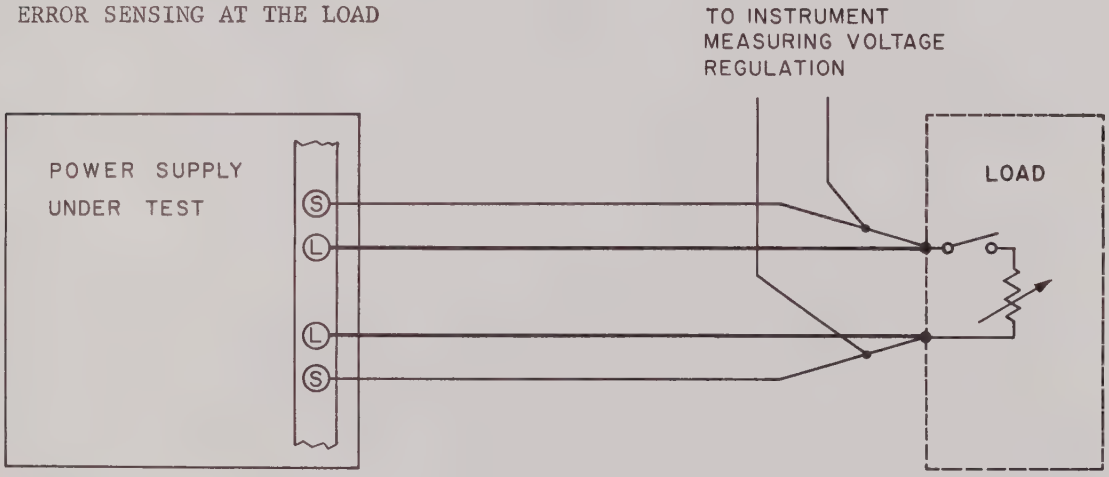
5-12 POWER SUPPLY MEASUREMENTS (Refer To Fig. 5-3)

5-13 Measurement of the significant parameters of a power supply is a requirement for incoming inspection, periodic maintenance or after component replacement. Since these measurements require special techniques to insure correct results, suggestions for their performance are given below:

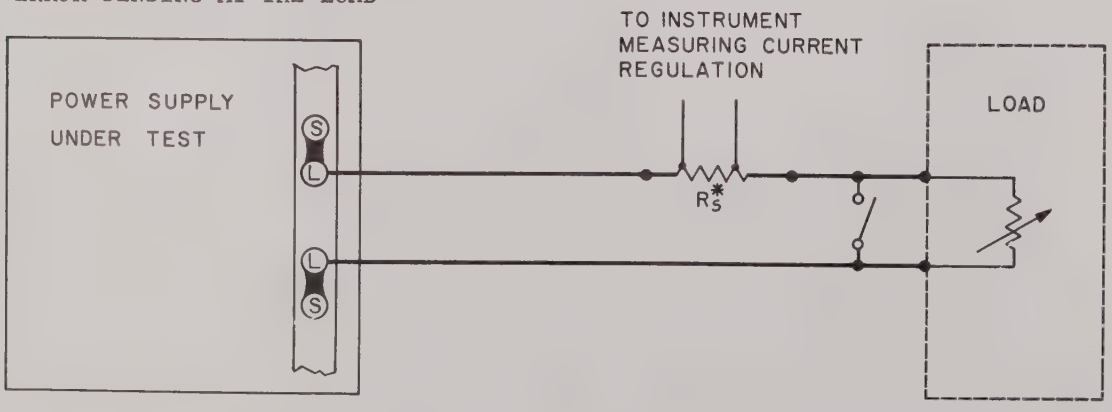
FIG. 5-3 POWER SUPPLY MEASUREMENTS, CONNECTING METHODS



A) REGULATION MEASUREMENT (VOLTAGE) WITHOUT ERROR SENSING AT THE LOAD



B) REGULATION MEASUREMENT (VOLTAGE) WITH ERROR SENSING AT THE LOAD



C) REGULATION MEASUREMENT (CURRENT)

*R_S SHOULD BE SELECTED SUCH THAT ITS WATTAGE RATING IS AT LEAST 10 TIMES THE ACTUAL POWER DISSIPATED. STABILITY AND REGULATION DEPEND ON THE STABILITY OF R_S. RECOMMENDED T.C. FOR R_S IS 20 PPM.

a) Required Instrumentation:

1) Constant AC supply voltage with provisions for "stepping" the voltage over a specified region (105-125V); a variable autotransformer is generally adequate, it is rated to deliver the input current of the unit under test.

2) Resistive load, variable, with ON and OFF switch and capable of dissipating the full output power of the unit under test.

3) DC voltage monitor, differential voltmeter, or power supply analyzer such as the KEPCO Regulation Analyzer 901D which displays the percentage regulation directly.

4) Current sensing resistor, for current regulation measurements, four-terminal device.

5) AC ripple monitor, sensitivity better than 1 mv, (self-contained in the Kepco 901D, Ballantine Model 302C, or Hewlett Packard Model 400H.

6) Optional: Oscilloscope, vertical sensitivity better than 1 mv/m.

b) The Four-Terminal Network is an essential device for precise measurement of regulation. It can be approximated by the method shown in Fig. 5-4.

Fig. 5-3 shows the proper location of instrument leads when measuring regulation. The principle governing this method of measurement is simply not to measure any voltage drops due to load current flow. This can only be avoided by measuring regulation either directly at the sensing leads or by the use of the four-terminal network.

c) Voltage Regulation is defined as the amount of output voltage change resulting from a specified change of line voltage or from a change in load resistance. It can be expressed as an absolute change ΔV or as a percentage in reference to the total output voltage E_o,:

$$\% \text{ Voltage Regulation} = \frac{\Delta V}{E_o} \times 100.$$

d) Current Regulation is defined as the amount of output current change resulting from a specified change in line voltage or from a change in load resistance. It can be expressed as an absolute change ΔI, or as a percentage in reference to the total output current I_b,:

$$\% \text{ Current Regulation} = \frac{\Delta I}{I_o} \times 100.$$

e) Ripple: RMS ripple may be monitored on a true RMS reading instrument connected parallel to the regulation analyzer leads. Careful wire dressing and shielding, as well as good A.C. grounding are of the utmost importance if valid measurements are being expected. An oscilloscope may also be used for P-P readings of noise and ripple. An approximate RMS reading can be calculated from the P-P reading of the oscilloscope if the reading is divided by three.

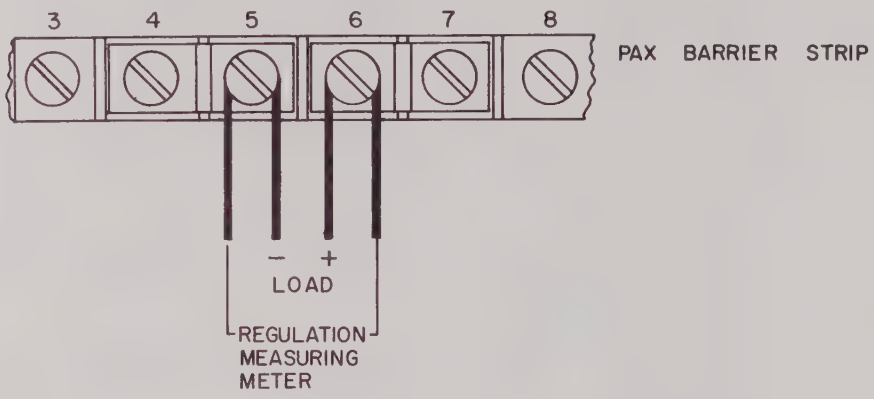
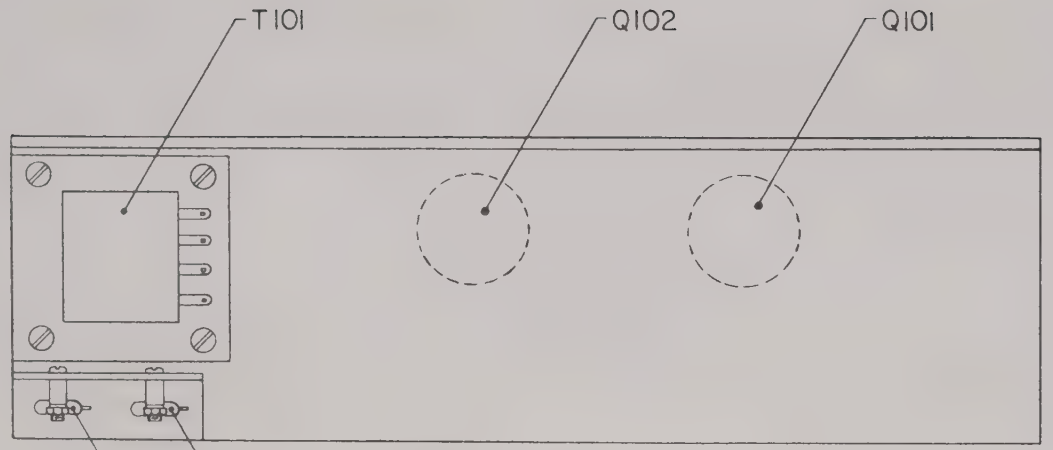


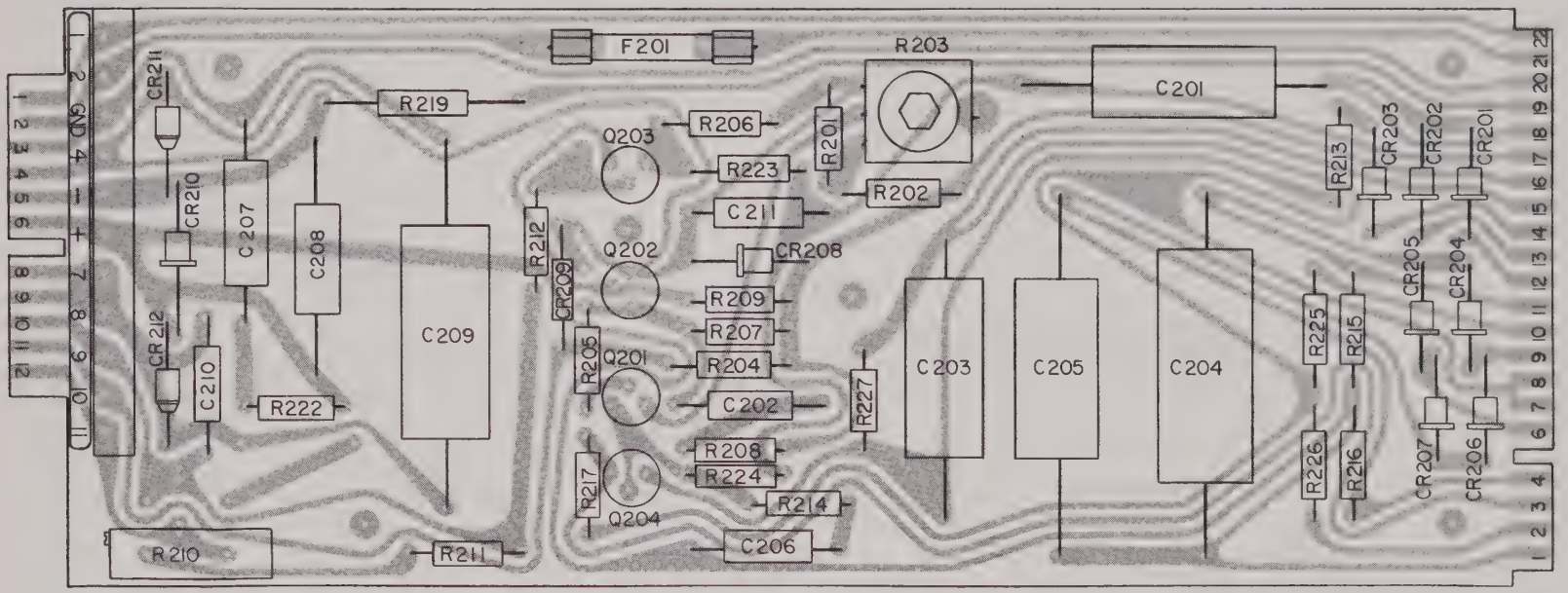
FIG. 5-4 APPROXIMATION OF A FOUR TERMINAL NETWORK



NOTE:

1. USED FOR MODELS
   PAX 7-1, PAX 7-1HS
   PAX 15-0.75, PAX 15-0.75HS
   PAX 21-0.5, PAX 21-0.5HS
   PAX 36-0.3, PAX 36-0.3HS
   PAX 72-0.15, PAX 72-0.15 HS
   PAX100-0.1, PAX100-0.1HS
2. Q102 IS NOT USED ON MODELS
   PAX 72-0.15, PAX 72-0.15 HS
   PAX 100-0.1, PAX100-0.1HS

FIG. 5-5 COMPONENT LOCATION, MAIN CHASSIS

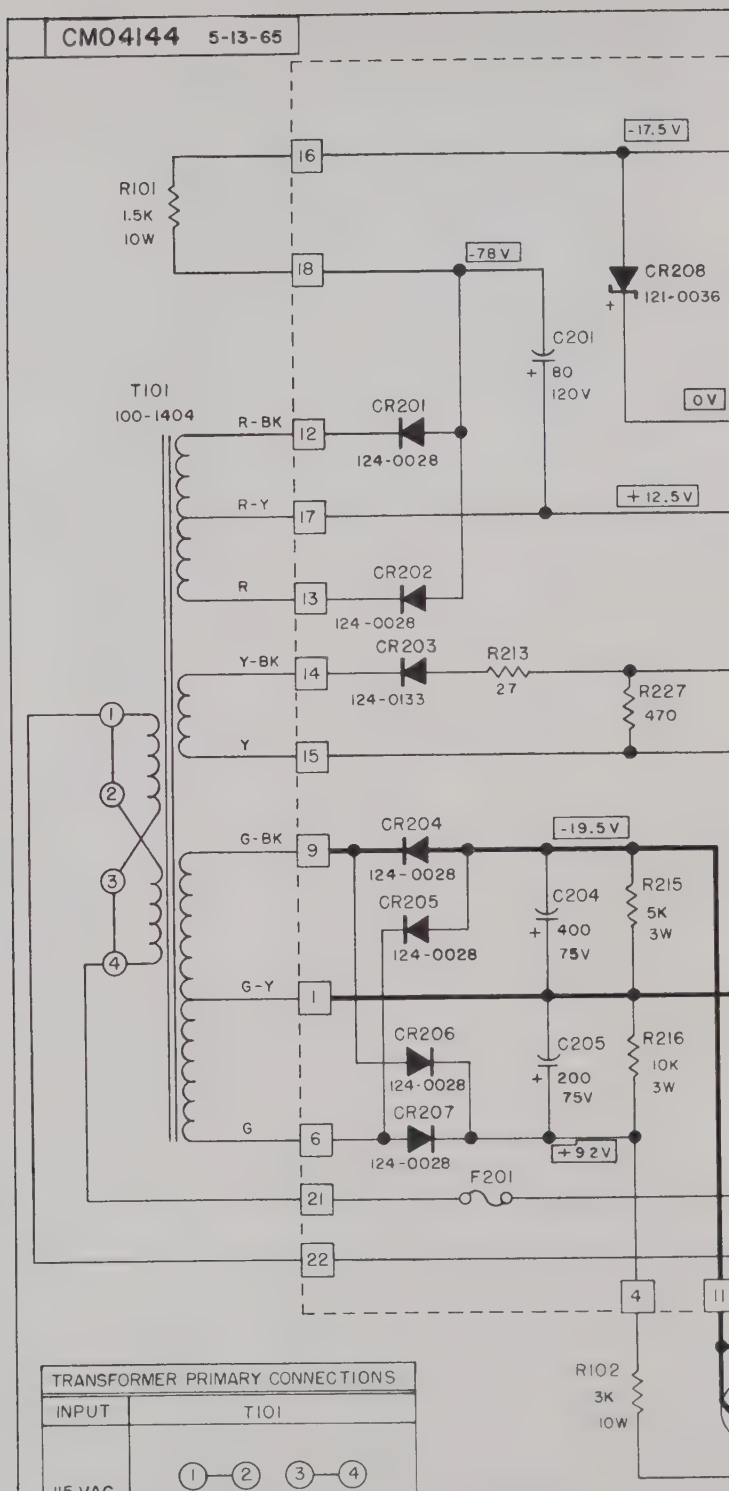


NOTES:

1. R226 NOT USED ON:
   PAX 72-0.15
   PAX 100-0.2
2. R225 IS DESIGNATED AS R228 ON:
   PAX 72-0.15
   PAX 100-0.2
3. R210 IS ONLY USED ONLY IN UNITS BEARING AN "R" BEHIND THEIR MODEL NO.

FIG. 5-6 COMPONENT LOCATION, PCB-1

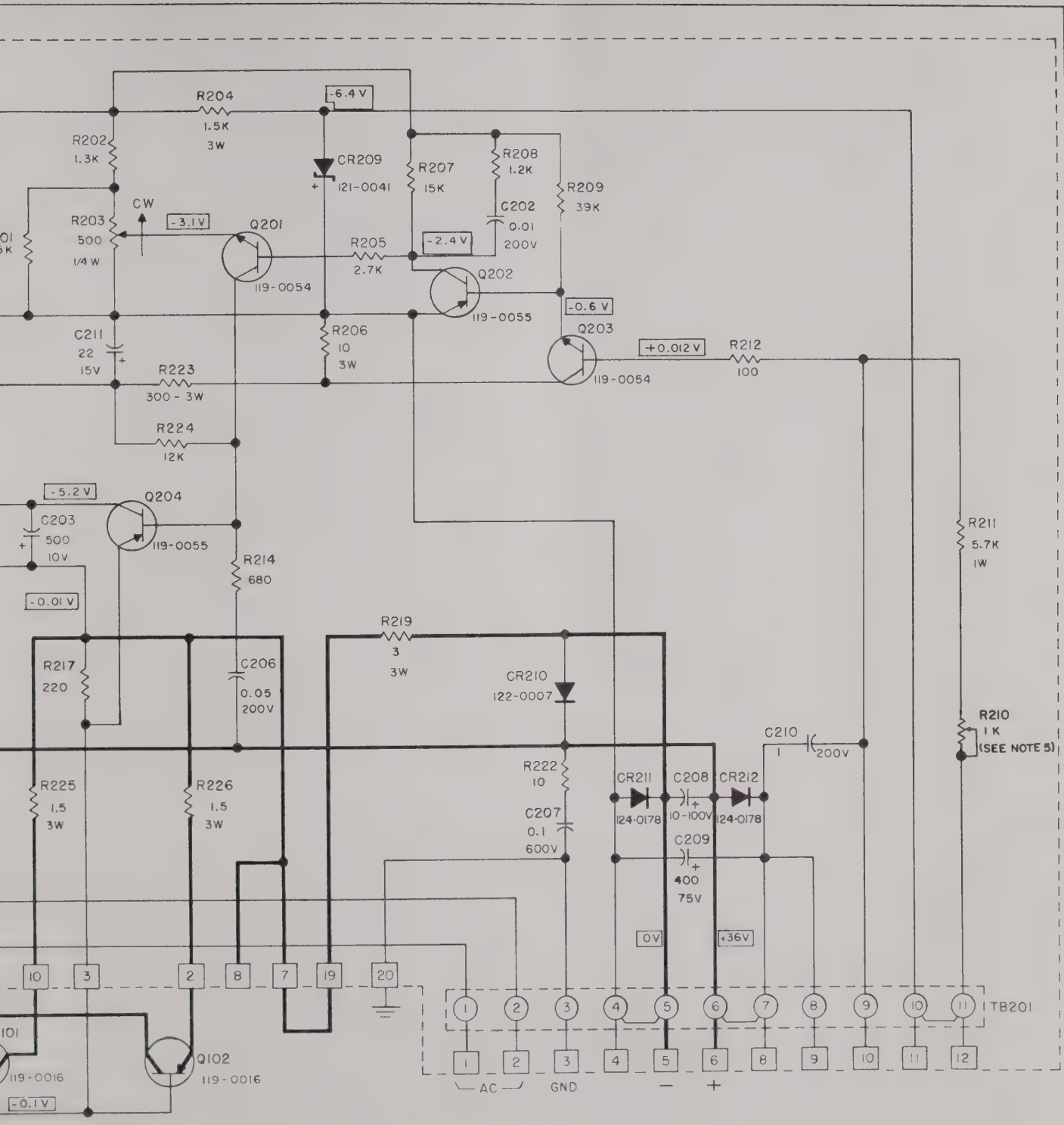
CM04144 5-13-65



TRANSFORMER PRIMARY CONNECTIONS	
INPUT	T101
115 VAC	① — ② ③ — ④
	F201: 0.5A SLO BLO
230 VAC	① ② — ③ ④
	F201: 0.3A SLO BLO

NOTES:

1. ALL RESISTORS A
   ALL CAPACITOR V
2. VOLTAGES ARE D
   AC LINE 115V; OU
3. ALL COMPONENTS
4. ORDER REPLACE
5. R210 USED IN UNI



1/2 WATT UNLESS OTHERWISE SPECIFIED; VALUES IN OHMS, K=1000 OHMS
S IN MICROFARADS.
YPICAL VALUE, & MEASURED TO (-) DC OUTPUT TERMINAL WITH 20K/V METER;
T SET TO MAXIMUM VDC WITH NO LOAD.
THIN DOTTED LINE ARE LOCATED ON PRINTED CIRCUIT BOARD.
T PARTS BY KEPCO PART NUMBER. SEE PARTS LIST.
EARING AN "R" BEHIND THEIR MODEL NO.

FIG. 5-7 MAIN SCHEMATIC, MODEL PAX 36-0.3 (C) (R)

MAIN CHASSIS, MODEL PAX 36-0.3 (C) (R) Code 7-364

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
Q101,102	2	Transistor,PNP	Delco 2N174	119-0016
R101	1	Resistor,Fixed,Power,Strip 1.5 K ohm, 10 w, 5%	Hardwick Hindle B-360	115-1159
R102	1	Resistor,Fixed,Power,Strip 3 K ohm, 10 w, 5%	Hardwick Hindle 3/4 BR56-3000	115-1205
T101	1	Transformer	Kepco Magnetics	100-1404

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

kepco inc.®

REPLACEMENT PARTS LIST

PRINTED CIRCUIT BOARD, MODEL PAX 36-0.3 (C) (R) Code 5-1365

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C201	1	Capacitor, Electrolytic, Pigtail 80 µf, 120 v	General Electric 43F7515AA1	117-0427
C202	1	Capacitor, Mylar 0.01 µf, 200 v, 10%	Sprague Electric 192P10302	117-0353
C203	1	Capacitor, Electrolytic, Pigtail 500 µf, 10 v	General Electric 43F7572AA1	117-0428
C204, 209	2	Capacitor, Electrolytic, Pigtail 400 µf, 75 v	General Electric 43F7573AA1	117-0432
C205	1	Capacitor, Electrolytic, Pigtail 200 µf, 75 v	General Electric 43F7574AA1	117-0436
C206	1	Capacitor, Mylar 0.05 µf, 200 v, 10%	TRW Type X663F	117-0362
C207	1	Capacitor, Mylar 0.1 µf, 600 v, 20%	TRW Type X663F	117-0316
C208	1	Capacitor, Electrolytic, Pigtail 10 µf, 100 v, 10%	General Electric 76F02ML100	117-0439
C210	1	Capacitor, Mylar, Pigtail 1 µf, 200 v, 10%	Good All X663FR	117-0395
C211	1	Capacitor, Electrolytic, Pigtail 22 µf, 15 v, 20%	General Electric 76F02FD220	117-0444
CR201, 202, 204-207	6	Rectifier, Silicon, Pigtail	Semicon Inc. SM-140	124-0028
CR203	1	Rectifier, Silicon, Pigtail	Semicon Inc. SM-110	124-0133
CR208	1	Zener Diode	Motorola 1N3026B	121-0036
CR209	1	Zener Diode	North American 1N821	121-0041
CR210	1	Rectifier, Germanium, Pigtail	General Electric 1N91	122-0007
CR211, 212	2	Rectifier, Silicon, Pigtail	Solitron Devices 124-0178	124-0178
F201	1	Fuse, Slo Blo 0.5 a	Bussman MDL-1/2	141-0036
Q201, 203	2	Transistor, Silicon, NPN	General Electric 2N338	119-0054
Q202, 204	2	Transistor, Silicon, PNP	Hughes 2N1131A	119-0055
R201	1	Resistor, Fixed, Molded 1.5 K ohm, 1/2 w, 10%	Allen Bradley EB1521	115-0578
R202	1	Resistor, Fixed, Molded 1.3 K ohm, 1/2 w, 5%	Allen Bradley EB1325	115-1600

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

kepco inc. ® REPLACEMENT PARTS LIST

PRINTED CIRCUIT BOARD MODEL PAX 36-0.3 (C) (R) Code 5-1365

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R203	1	Resistor, Variable, Composition 500 ohm, 1/4 w, 30%	C.T.S. V-151	115-1605
R204	1	Resistor, Fixed, Precision, WW 1.5 K ohm, 3 w, 3%	Tepro Electric TS3W	115-1601
R205	1	Resistor, Fixed, Molded 2.7 K ohm, 1/2 w, 10%	Allen Bradley EB2721	115-0560
R206	1	Resistor, Fixed, Power, Axial 10 ohm, 3 w, 5%	Ward Leonard 3X10	115-0421
R207	1	Resistor, Fixed, Molded 15 K ohm, 1/2 w, 10%	Allen Bradley EB1531	115-1152
R208	1	Resistor, Fixed, Molded 1.2 K ohm, 1/2 w, 10%	Allen Bradley EB1221	115-1129
R209	1	Resistor, Fixed, Molded 39 K ohm, 1/2 w, 10%	Allen Bradley EB3931	115-1137
*R210	1	Resistor, Variable, W.W. 1 K ohm	Bourns 3067S-1-102	115-0739
R211	1	Resistor, Fixed, Precision, WW 5.7 K ohm, 1 w, 1%	Tepro Electric TS1W	115-1301
R212	1	Resistor, Fixed, Molded 100 ohm, 1/2 w, 10%	Allen Bradley EB1011	115-0626
R213	1	Resistor, Fixed, Molded 27 ohm, 1/2 w, 10%	Allen Bradley EB2701	115-0861
R214	1	Resistor, Fixed, Molded 2 K ohm, 1/2 w, 5%	Allen Bradley EB2025	115-0520
R215	1	Resistor, Fixed, Power, Axial 5 K ohm, 3 w, 5%	Hardwick Hindle 9/16 GA5000 LTC	115-1094
R216	1	Resistor, Fixed, Power, Axial 10 K ohm, 3 w, 5%	Sprague Electric 151E-10K	115-0460
R217	1	Resistor, Fixed, Molded 220 ohm, 1/2 w, 10%	Allen Bradley EB2211	115-0371
R219	1	Resistor, Fixed, Power, Axial 3 ohm, 2 w, 5%	Tepro Electric TS2W	115-1616
R222	1	Resistor, Fixed, Molded 10 ohm, 1/2 w, 10%	Allen Bradley EB1001	115-0502
R223	1	Resistor, Fixed, Power, Axial 300 ohm, 3 w, 5%	Ward Leonard 3X300	115-0444
R224	1	Resistor, Fixed, Molded 12 K ohm, 1/2 w, 10%	Allen Bradley EB1231	115-1168
R225, 226	2	Resistor, Fixed, Power, Axial 1.5 ohm, 3 w, 5%	Ward Leonard 3X1.5	115-0517
R227	1	Resistor, Fixed, Molded 470 ohm, 1/2 w, 10%	Allen Bradley EB4711	115-0608

*IN MODEL PAX 36-0.3R ONLY.

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

131-38 SANFORD AVENUE • FLUSHING, N.Y. 11352 • Phone (212) IN 1-7000
TWX# 212-539-6623 • Cable Address: KEPCOPOWER NEWYORK

146-0045 2/65